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THE ELASTIC ARCH.

DEAN GALBRAITH

Faculty of Applied Science and Engineering,

University of Toronto.

The subject of this paper is the theory of the graphical method used in connection with the design and computation of the elastic arch. The treatment is not intended to be complete but is directed specially to difficulties which have been brought to my attention by some of our graduates engaged in the design of reinforced concrete arches.

The method is originally due to Professor H. T. Eddy, now of the University of Minnesota, who published his results between 1876 and 1878. Professor Wm. Cain of the University of North Carolina was also one of the early contributors to the subject.

As a basis for the graphical method the general treatment of the arch will be first considered.

The arch is statically indeterminate, and in all treatments the three statical equations require to be supplemented by three others. On the assumption that the arch is inelastic the requisite equations are obtained by, in effect, the more or less arbitrary assumption of the positions of the centres of pressure at three cross-sections, e.g., the springing planes and the section at the apex. If on the other hand Young's modulus for the material be known, the conditions of elasticity and the methods of fixing the ends will furnish the three necessary conditions.

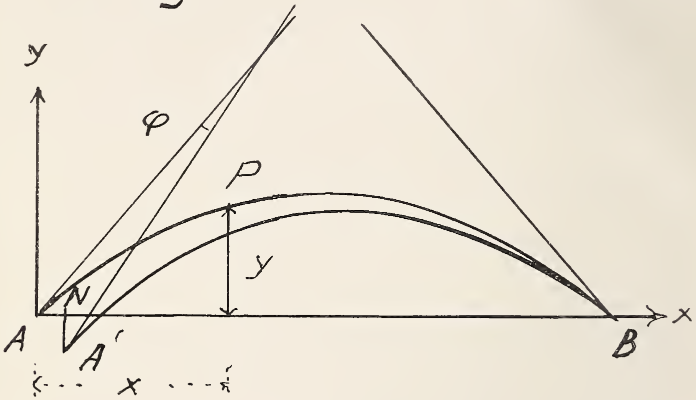
The Elastic Curved Beam.

The following theorems respecting the elastic curved beam will be stated without proof. (See Fig. 1.)

Let A B represent the axis of the curved beam when under a given loading, A' B the form of the axis when unstressed. Let the two curves be made to coincide in position and direction at the end B then at the ends A and A' the curves will in general differ both in position and direction.

Assume as rectangular axes of reference ABx and Ay and let ϕ denote the angle between the directions of the tangents at A and A'. Let $AN = x'$, $NA' = y'$ be the co-ordinates of A', then it may be shown that

Fig. 1



$$1.\quad \phi = \int^{B} \frac{M}{EI}\,ds; \qquad 2.\quad x' = \int_{A}^{B} \frac{My}{EI}\,ds; \qquad 3.\quad y' = -\int_{A}^{B} \frac{Mx}{EI}\,ds;$$

where x and y are the coordinates of P the current point on the curve AB, s the distance along the curve from A to P, M the bending moment at the cross-section at P, I the moment of inertia of the cross-section at P and E Young's modulus for the material of the beam. It is assumed that x' and y' are small compared with the greatest values of x and y respectively, and the lengths of AB and $A'B$ are considered equal.

The Elastic Arch with Fixed Ends.

It will be sufficient for the purpose of this paper to consider only the above arch. The loading will be assumed vertical and the form of the arch symmetrical with regard to a vertical through the apex.

In the case of a composite material such as reinforced concrete, EI will represent the composite expression $E_1\ (I_1 + nI_2)$.

The axis of the arch (often termed the neutral line) is the locus of the centres of gravity of the cross-sections of the arch if the material is homogeneous; in the case of reinforced concrete the cross-section of the steel is replaced by its concrete equivalent for the purpose of determining the centre of gravity. The axis of the arch and the cross-sections are at right angles to each other.

A bending moment M will be considered positive when it tends to make the arch concave upwards.

It is evident that in the case of the arch with fixed ends

1. $\phi = 0$; 2. $x' = 0$; 3. $y' = 0$.

Thus in this arch the following conditions hold, viz:

$$1.\ \int^{B} \frac{M}{EI}\,ds = 0; \qquad 2.\ \int_{A}^{B} \frac{My}{EI}\,ds = 0; \qquad 3.\ \int_{A}^{B} \frac{Mx}{EI}\,ds = 0;$$

When the various quantities are not expressible as functions of x as is usually the case, the indicated integration must be replaced by graphical summation. In doing this the general principle involved is to make the subdivisions δs of the axis so short that the values of x, y, M, E and I corresponding to the middle points of the subdivisions may be used in the summations without producing serious error. The subdivision of the arch is thus more or less a matter of judgment. It should be founded on comparisons between the results of computations made with longer and shorter subdivisions.

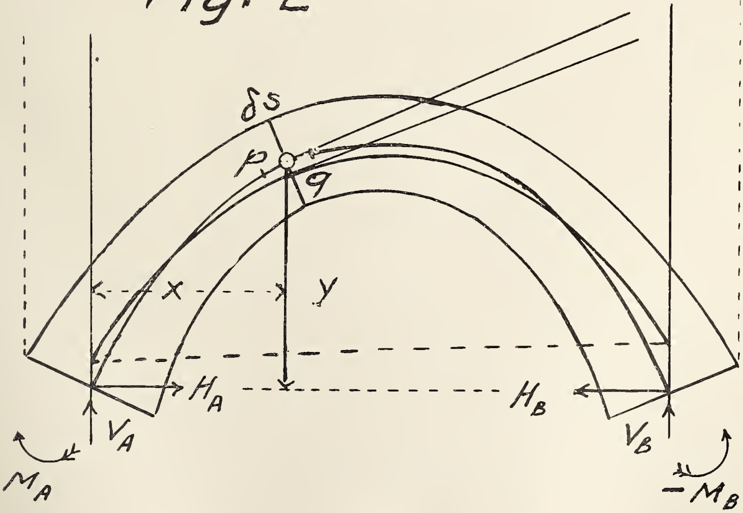
Subject to these considerations the following method of subdivision is sometimes used. The axis is divided by trial into subdivisions for which $\frac{\delta s}{EI}$ is constant or, if E is constant throughout the arch, for which $\frac{\delta s}{I}$ is constant.

The three conditions above found will then reduce to

1. $\Sigma M = 0$; 2. $\Sigma My = 0$; 3. $\Sigma Mx = 0$.

omitting for the sake of brevity the limit symbols A and B.

Fig. 2



It follows at once from these equations that the values of M throughout the arch cannot all have the same sign.

Fig. 2 is a diagram of the arch showing a type subdivision δs, the coordinates x and y of its centre point, the supporting forces and couples V_a, H_a and M_a at the end A and V_b, H_b and $-M_b$ at the end B; the loading is not shown.

The bending moment M corresponding to any subdivision δs of the axis, that is the bending moment at the cross-section of the arch having its centre of gravity at the point x, y, may be considered as arising from the algebraic addition of three bending moments M', M'', M''' defined as follows:

M' is the bending moment due to the loading (see remarks) computed on the supposition that the arch is supported by vertical forces V'_a and V'_b as in the case of the freely supported horizontal beam.

M'' is due to the bending moments M_a and M_b at the end cross-sections. It is computed by assuming the arch to be maintained in equilibrium by fixing couples M_a and $-M_b$ at the ends together with a third couple composed of equal and opposite vertical forces V''_a, V''_b acting at A and B respectively.

M''' is due to the horizontal thrust H of the abutments.

From the conditions of equilibrium defining M'' and M''' it may be easily shown that

$$M'' = M_a + \frac{M_b - M_a}{l}x \text{ where } l \text{ is the span } AB.$$

also $M''' = -Hy$ assuming H to be thrust and positive.

$$\text{Thus } M = M' + M'' + M''' = M' + M_a + \frac{M_b - M_a}{l}x - Hy.$$

Then we have, if n denote the number of subdivisions δs of the axis,

$$1. \quad \Sigma M = \Sigma M' + nM_a + \frac{M_b - M_a}{l}\Sigma x - H\Sigma y = 0$$

$$2. \quad \Sigma My = \Sigma M'y + M_a\Sigma y + \frac{M_b - M_a}{l}\Sigma xy - H\Sigma y^2 = 0$$

$$3. \quad \Sigma Mx = \Sigma M'x + M_a\Sigma x + \frac{M_b - M_a}{l}\Sigma x^2 - H\Sigma xy = 0$$

the summations being taken from A to B.

Now $\Sigma M'$, $\Sigma M'y$, $\Sigma M'x$ and Σx, Σy, Σx^2, Σxy, Σy^2 may be computed from the loading and from the coordinates of the n points x, y, taken on the axis. Hence the above three equations will determine M_a, M_b and H to any degree of approximation desired. The approximation becomes closer as the lengths of the subdivisions are taken smaller.

M can now be determined from its equation for each of the n values of x.

H will denote an abutment thrust if positive, a tension if negative, so that the horizontal abutment reactions H_a and H_b become determined in both magnitude and sense.

Since the bending moment M_a and M_b are known the fixing couples M_a and $-M_b$ are determined.

NOTE—Lower case subscript letters in the text represent corresponding upper case letters in the diagrams.

Finally, the vertical abutment reactions V_a and V_b are determined from the equation of vertical resolved parts of the external forces and the equation of moments.

The positive senses adopted will be: For forces, upwards, to the right and clockwise; for stresses, thrust, shear lengthening the diagonal in a vertical rectangle from upper lefthand corner, bending producing concavity upwards.

On computing V'_a, V'_b and V''_a, V''_b from their definitions it will be found that

$$V_a = V'_a + V''_a;\ V_b = V'_b + V''_b$$

The thrusts and shears at any cross-section of the arch may now be determined.

H having been determined we may write $M'' = Hy''$, $M' = Hy'$, also $M''' = -Hy$, thus $M = H\ (y'' + y' - y)$ and the three end conditions may be written:

1. $\Sigma\ (y'' + y' - y) \qquad = 0$
2. $\Sigma\ (y'' + y' - y)\ y \qquad = 0$
3. $\Sigma\ (y'' + y' - y)\ x \qquad = 0$

4. Where $y'' = \dfrac{M''}{H} = \dfrac{M_a}{H} + \dfrac{\dfrac{M_b}{H} - \dfrac{M_a}{H}}{l}\ x$

5. and $y' = \dfrac{M'}{H}$

a result which will be used in the explanation of the graphical method.

This completes the resumé of the general method of computing the elastic arch with fixed ends.

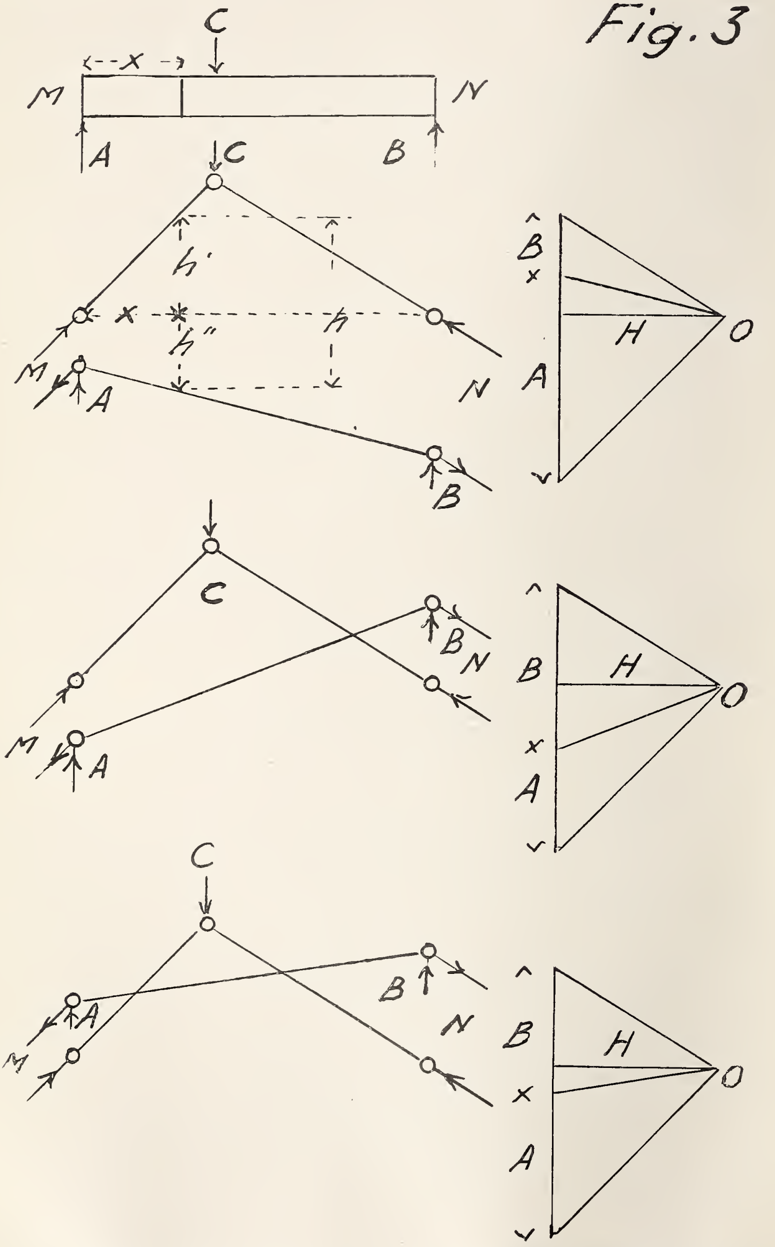
Graphical Computation.

It may be useful to begin with a simple problem involving end couples.

Thus suppose a beam (see Fig. 3) supporting a single load C and acted on by given couples of moments M and N at the ends. Let it be required to determine graphically the supporting vertical reactions A and B. Three cases are worked out in the figure.

Construct the polar diagram and the funicular or equilibrium polygon for the load; then lay off the couples having the moments M and N using as forces the end forces acting on the arms of the funicular polygon of the load and forces equal and opposite to these as shown in the diagrams. The line joining the intersections of the latter forces with the end verticals will be the closing line or closing arm of the complete funicular polygon. A more accurate method of constructing the end points of the closing line is to lay off vertical ordinates in the proper senses (shown in the figure) from the end points of the funicular polygon of the loading, viz., the ordinate $\dfrac{M}{H}$ at the left and the ordinate $\frac{N}{H}$ at the right-hand end. H is the horizontal pole distance in pounds.

Fig. 3



A line drawn from the pole O in the polar diagram parallel to this closing line will divide the vertical load line into two portions representing A and B as shown.

It is evident that if the end couples be altered by equal absolute amounts the reactions A and B will remain unaltered, for the new closing line will be parallel to the old.

The bending moment at any section x is Hh when h is the vertical ordinate drawn from the closing line to meet the funicular polygon of the loading.

Writing $h = h' + h''$ where h'' runs from the closing line to meet the line joining the end points of the funicular polygon of the loading, we shall have Hh' representing the bending moment at x if no end couples act and Hh'' the bending moment due to the end couples M and N if no loading exists and if equilibrium be maintained by equal and opposite vertical reactions A'' and B'' at the ends. It is evident that if A' and B' be the vertical end reactions due to the loading alone $A' + A'' = A$ and $B' + B'' = B$; also $Hh'' = M + \frac{N - M}{l} x$ where l represents the span.

The complete funicular polygon considered as a jointed frame is thus divided on account of the end couples into two parts, each part being in equilibrium under external forces. Thus no stress exists between these parts when considered as parts of a jointed frame.

If the forces of the end couples be represented in the polar diagram and the funicular polygon be drawn in the ordinary way the portion of this polygon between the end verticals is the funicular polygon shown in Fig. 3.

Construct (see Fig. 4) the funicular or equilibrium polygon $A'\ C'\ B'$ for the vertical loading by means of a polar diagram having any convenient pole. Any suitable divisions of the arch may be used for this purpose since this diagram is entirely independent of the variation of the quantity EI which determines the n subdivisions δs used in the summations 1, 2, 3. The annexed diagram is drawn on the supposition that the subdivisions are infinitely small. A', B' are in the same verticals as A, B.

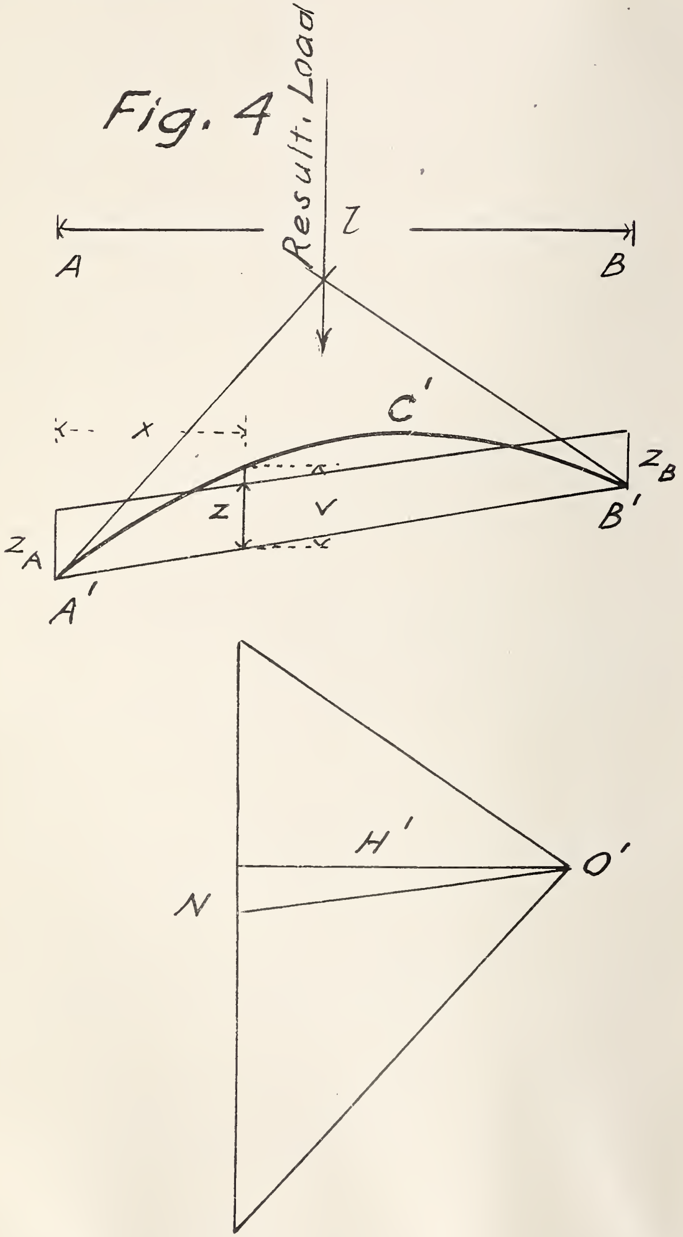
If then x denote the abscissa of the middle point x, y, of one of the n subdivisions δs of the axis and v the ordinate of the equilibrium polygon corresponding to x the bending moment corresponding to this point due to the vertical loading will be given by $M' = H'v$ where H' is the horizontal pole distance in pounds. (See remarks.)

Now construct a straight line on the same base $A'\ B'$, the ordinates z of which for each value of x are so related to the ordinates v of the above equilibrium polygon that
$\Sigma z = \Sigma v$ and $\Sigma zx = \Sigma vx$ summing from A' to B'; thus
$\Sigma(v - z) = 0$; $\Sigma(v - z)x = 0$.

It must be noticed that the above summations do not include any ordinates except those corresponding to the values of x for the middle points of the n divisions δs of the arch.

Evidently $z = z_a + \frac{z_b - z_a}{l} x$ where z_a and z_b represent the end ordinates of the z line.

Fig. 4



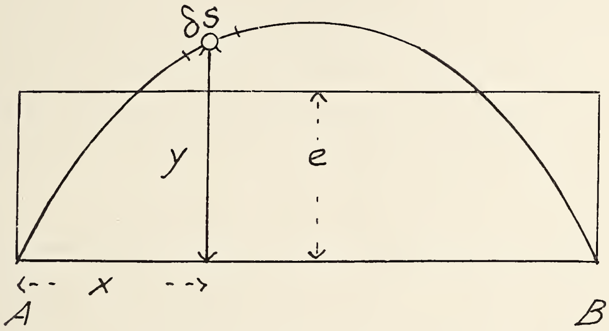
In a similar manner construct (see Fig. 5) from the n ordinates y of the axis of the arch a straight line of which the ordinates e for the several values of x fulfil the conditions

$$\Sigma e = \Sigma y; \ \Sigma ex = \Sigma yx$$

and thus

$$\Sigma(y - e) = 0; \ \Sigma(y - e)x = 0$$

Fig. 5



Since the axis is symmetrical with regard to its apex evidently e will be constant for all values of x and will fulfil the condition

$$ne = \Sigma y \text{ or } e = \frac{\Sigma y}{n}$$

In this case the condition $\Sigma ex = \Sigma yx$ is fulfilled necessarily and is therefore not an independent condition; if not obvious this may be shown as follows:

From symmetry:

$$\Sigma ex = \Sigma e(l - x) = \Sigma el - \Sigma ex \text{ where } l = \text{span } AB.$$

$$\therefore 2\Sigma ex = \Sigma el = nel$$

$$\therefore \Sigma ex = \frac{nel}{2}$$

also $\Sigma yx = \Sigma y(l - x) = \Sigma yl - \Sigma yx$

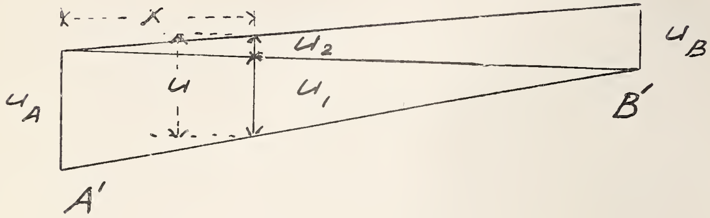
$$\therefore 2\Sigma yx = \Sigma yl = l\Sigma y = lne$$

$$\therefore \Sigma yx = \frac{lne}{2}$$

$$\therefore \Sigma yx = \Sigma ex.$$

Graphical Computation of z. (See Fig. 6.)

Fig. 6

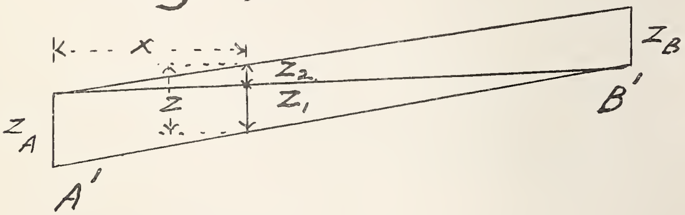


Draw any straight line to base $A'B'$ and let the ordinate corresponding to abscissa x be represented by u; draw the diagonal shown cutting the ordinates u each into two parts, a lower u_1 and an upper u_2 so that $u_1 + u_2 = u$.

Then write $\overline{x}_1 = \dfrac{\Sigma u_1 x}{\Sigma u_1}$; $\overline{x}_2 = \dfrac{\Sigma u_2 x}{\Sigma u_2}$

From the properties of the triangle it is evident that the values of $\overline{x}_1$ and $\overline{x}_2$ remain unchanged whatever be the values of u_a, u_b, hence the above construction will give the values of $\overline{x}_1$ and $\overline{x}_2$ for the z diagram (Fig. 7) even though the values of z are as yet unknown.

Fig. 7



Then drawing a similar diagonal in the z diagram we have

$$\frac{\Sigma z_1 x}{\Sigma z_1} = \overline{x}_1 \qquad \frac{\Sigma z_2 x}{\Sigma z_2} = \overline{x}_2$$

Also $\Sigma z_1 x + \Sigma z_2 x = \Sigma z x = \Sigma v x$ by hypothesis
and $\Sigma z_1 + \Sigma z_2 = \Sigma z = \quad = \Sigma v$ by hypothesis.
$\therefore \overline{x}_1 \Sigma z_1 + \overline{x}_2 \Sigma z_2 = \Sigma v x$; $\Sigma z_1 + \Sigma z_2 = \Sigma v$
which equations give the unknowns Σz_1 and Σz_2

$$\text{thus } \Sigma z_1 = \frac{\overline{x}_2 \Sigma v - \Sigma v x}{\overline{x}_2 - \overline{x}_1} \quad ; \quad \Sigma z_2 = \frac{\Sigma v x - \overline{x}_1 \Sigma v}{\overline{x}_2 - \overline{x}_1}$$

The following transformation may be more convenient for computation:

Write $\Sigma vx = \bar{x}\Sigma v$ and compute $\bar{x}$

$$\text{Then } \Sigma z_1 = \frac{x_2 - \bar{x}}{x_2 - x_1} \Sigma v \; ; \quad \Sigma z_2 = \frac{\bar{x} - x_1}{x_2 - x_1} \Sigma v.$$

Now from the properties of a triangle it is evident that

$$z_a = \frac{\Sigma z_1}{\Sigma u_1} u_a \text{ and } z_b = \frac{\Sigma z_2}{\Sigma u_2} u_b$$

so that substituting in these expressions the values already found for Σz_1 and Σz_2 the values of z_a and z_b become known.

The z diagram can now be constructed and the value of z determined by measurement or computation for each value of x.

The constructions Fig. 6 and Fig. 7 are usually made directly on Fig. 4.

It is evident that $\frac{u_a}{\Sigma u_1} = \frac{u_b}{\Sigma u_2}$ and that the u line may as well be drawn parallel to A' B' and one triangle computed instead of two.

Analytical Computation of z.

z may be computed analytically as follows:

$$\Sigma z = \Sigma v$$

$$\Sigma zx = \Sigma vx$$

$$z = z_a + \frac{z_b - z_a}{l} x$$

Substituting from the last equation in the first

$$nz_a + \frac{z_b - z_a}{l} \Sigma x = \Sigma v$$

Substituting similarly in the second equation

$$z_a \Sigma x + \frac{z_b - z_a}{l} \Sigma x^2 = \Sigma vx$$

$$\text{thus } \left(n - \frac{\Sigma x}{l} \right) z_a + \frac{\Sigma x}{l} z_b = \Sigma v$$

$$\left(\Sigma x - \frac{\Sigma x^2}{l} \right) z_a + \frac{\Sigma x^2}{l} z_b = \Sigma vx$$

which equations will give z_a and z_b in terms of the known quantities l, n, Σx, Σv, Σx^2, Σvx.

z may then be computed for each value of x.

$$\text{The results are } z_a = \frac{\Sigma v \Sigma x^2 - \Sigma x \Sigma vx}{n \Sigma x^2 - (\Sigma x)^2}$$

$$z_b = \frac{\Sigma v . \Sigma x^2 - \Sigma x . \Sigma vx + l \, (n \Sigma vx - \Sigma x \Sigma v)}{n \Sigma x^2 - (\Sigma x)^2}$$

$$z = \frac{\Sigma v \Sigma x^2 - \Sigma x \Sigma vx + x \, (n \Sigma vx - \Sigma x \Sigma v)}{n \Sigma x^2 - (\Sigma x)^2}$$

The z's and e's having been determined the next step is to compute the summations

$$\Sigma(v - z)y = P \qquad \Sigma(y - e)y = Q$$

Then writing $v' = \frac{Q}{P} v$; $z' = \frac{Q}{P} z$ we have $\Sigma z' = \Sigma v'$; $\Sigma z'x = \Sigma v'x$. Therefore

$$\begin{array}{ll} \Sigma(v' - z') = 0 & \Sigma(y - e) = 0 \\ \Sigma(v' - z')y = Q & \Sigma(y - e)y = Q \\ \Sigma(v' - z')x = 0 & \Sigma(y - e)x = 0 \end{array}$$

Hence by subtraction

1′ $\Sigma(e - z' + v' - y) = 0$

2′ $\Sigma(e - z' + v' - y)y = 0$

3′ $\Sigma(e - z' + v' - y)x = 0$

in which $e - z' = e - \left\{ z'_a + \frac{z'_b - z'_a}{l} x \right\}$

4′ That is $e - z' = e - z'_a + \frac{e - z'_b - (e - z'_a)}{l} x$

5′ $v' = \frac{Q}{P} v = \frac{M'}{\frac{P}{Q} H'}$

Comparing these equations with the equations already established, viz:

1. $\Sigma(y'' + y' - y) = 0$

2. $\Sigma(y'' + y' - y)y = 0$

3. $\Sigma(y'' + y' - y)x = 0$

4. $y'' = \frac{M_a}{H} + \frac{\frac{M_b}{H} - \frac{M_a}{H}}{l} x$

5. $y' = \frac{M'}{H}$

we see that both sets involve the quantities l, x, y and M' in the same way and that $e - z'_a$, $e - z'_b$, $\frac{P}{Q} H'$ of the first set and $\frac{M_a}{H}$, $\frac{M_b}{H}$, H of the second set are respectively involved in the same way.

Consequently

$$e - z'_a = \frac{M_a}{H}\ ;\ e - z'_b = \frac{M_b}{H}\ ;\quad \frac{P}{Q} H' = H$$

In other words the graphical construction gives the true values of the horizontal thrust and the bending moments at the ends of the arch.

Fig. 8 is now constructed from Fig. 4 by making $v' = \frac{Q}{P} v$, $z' = \frac{Q}{P} z$ and making the upper line of the z' diagram horizontal, its length being equal to l the span AB.

Fig. 8

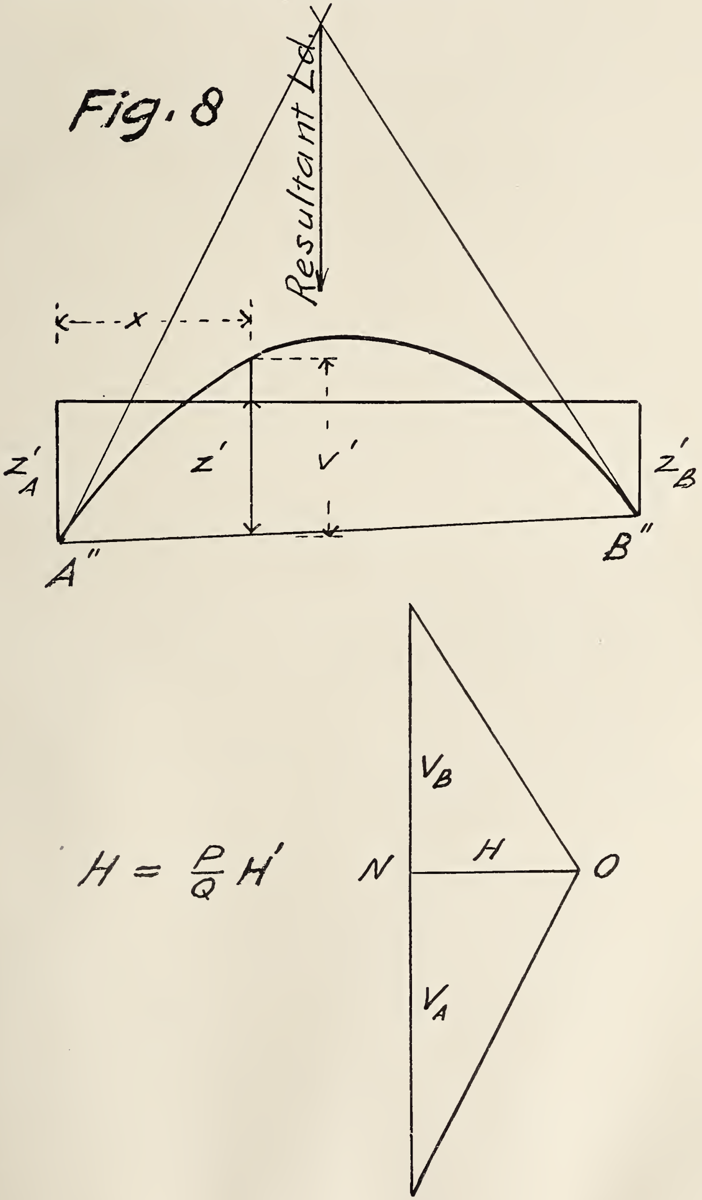


Fig. 9 is now constructed by applying Fig. 8 to Fig. 5 so that the horizontal z' line of the former coincides with the horizontal e line of the latter.

Draw the ordinate in Fig. 9 for abscissa x and let it cut the various lines in the points p, q, r, s, t. Evidently $ts = e - z'$; $sq = v'$ and $tp = y$. Thus $M = (ts + sq - tp)H = -qp \times H = pq \times H$. Hence the ordinate corresponding to M for any section x is that part of the ordinate at x intercepted between the axis of the arch and the curve of moments, reckoned positive if drawn upwards from the axis. In the figure this ordinate is negative.

The moment M'' due to the end couples M_a and $-M_b$ being equal to $(e - z')H$ or $He - Hz'$ may be analyzed as follows:

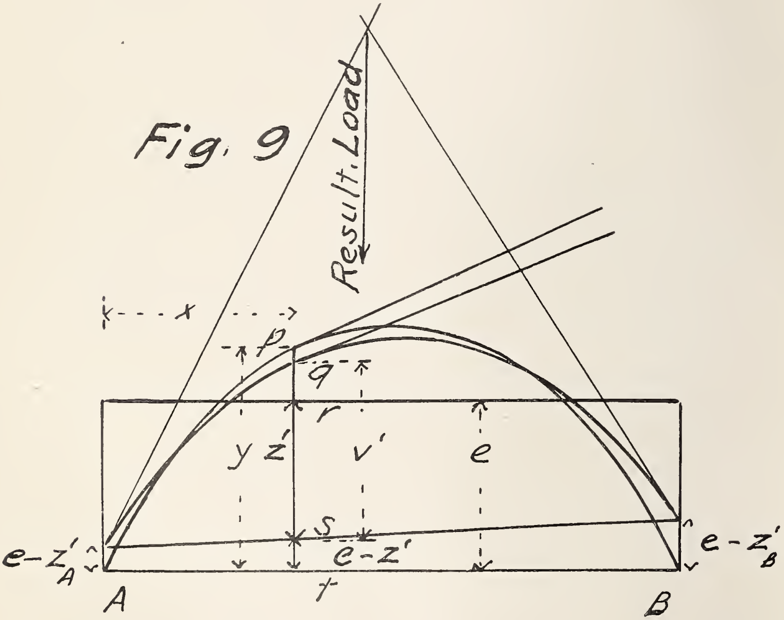


Fig. 9

The bending moment $-Hy$ due to the horizontal thrust of the abutments generates an opposing bending moment He due to the fixed directions of the axis at the abutments; the bending moment Hv' due to the vertical forces generates an opposing bending moment $-Hz$ due also to the fixed directions at the abutments and the sum of these $He - Hz'$ is the total bending moment due to the fixed directions at the abutments.

There are thus two bending moments Hv' and $-Hz'$ due to the vertical system of forces and two bending moments $-Hy$ and He due to the horizontal system of forces. The sum of these four moments is the resultant bending moment M.

The horizontal thrust H is itself due to the vertical system of forces, being caused by the action of the latter on the elastic body of the arch which is prevented from spreading by the fixed abutments.

Vertical Reactions at A and B.

These are obtained from the polar diagram Fig. 8. It is constructed as follows: from the pole O' Fig. 4, draw a line $O\ N$ parallel to the closing line (the z line) to meet the load line, and transfer the point N so obtained to the load line of the polar diagram of Fig. 8. From N in the latter diagram lay off horizontally a line representing the true horizontal thrust H; the end O of this line represents the correct position of the pole in Fig. 8 and the point N divides the load line into the portions representing the vertical reactions V_a and V_b as indicated. The reasons are as follows:

The z line in Figure 4 is the closing line due to the combination of the loading with end couples of moments $-H'z_a$ and $+H'z_b$; these moments by construction are equal to $-Hz'_a$ and $+Hz'_b$, therefore the vertical reactions in the combination represented in Fig. 8 must be the same as in the case of Fig. 4. Now the closing line in Fig. 8 is horizontal; hence if H be laid off horizontally from N in Fig. 8 as shown, the proper position of the pole O will be found for the combination shown in Fig. 8. The true end moments indicated in Fig. 9, viz., $M_a = H(e - z'_a)$ and $-M_b = -H(e - z'_b)$ are not the same as the end moments in the case of Fig. 8 which are $-Hz'_a$ and $+Hz'_b$. However, they also give a horizontal closing line, viz., the base $A\ B$ of Fig. 9, so that the position of N in Fig. 8 indicates the true vertical end reactions. See discussion of Fig. 3.

Thrusts and Shears at a Cross-Section.

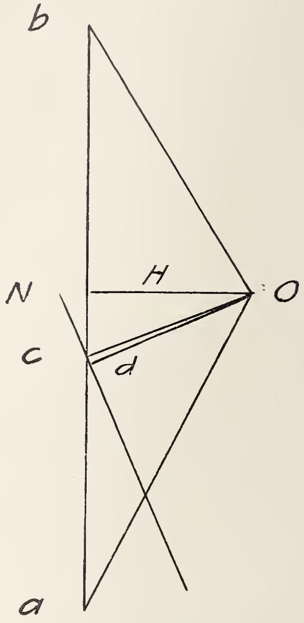
Consider the cross-section corresponding to x.

In the polar diagram of Fig. 8 let $c\ a$ (see Fig. 10) represent the load between the verticals at A and x; join $O\ c$; draw $c\ d$ parallel to the cross-section at x and drop the perpendicular $O\ d$ on $c\ d$. Then it is evident that $c\ O$ represents the oblique thrust on the cross-section, $c\ d$ its tangential resolved part or the shear (negative by the rule of signs) and $d\ O$ the normal thrust.

The position of the point of action on the cross-section, of the thrust $c\ O$, is obtained by drawing the tangent to the v' curve at the point corresponding to x to meet the cross-section in question. It nearly coincides with the point of intersection of the v' curve with the cross-section.

Evidently $O\ d$ is parallel to the tangent to the axis at p and $O\ c$ parallel to the tangent to the v' curve at q in Fig. 9 or Fig. 2.

Fig. 10



Remarks.

In this investigation the shortening of the elastic arch arising from the axial thrusts at the various cross-sections has not been taken into consideration nor the effects due to temperature changes.

The loading has been assumed to be vertical; that is to say no horizontal or spandrel reactions due to the load have been considered. The horizontal thrust is thus constant from abutment to abutment.

In computing the bending moment M' due to the loading, the load from the abutment up to the section in question has been assumed to be the weight of the material (including that in the arch itself) which lies between the verticals drawn through the axial points of the springing section A or B and of the section considered; similarly the whole load on the arch has been assumed to be the weight of the material (including that in the arch) lying between the verticals through the axial points A and B at the springing planes. The weights of the portions of the arch outside of these verticals and their super-incumbent loads have therefore not been included in the computation.

The errors due to this method of computing the bending moments due to the vertical loads, become less, the flatter the arch is, that is the more nearly it approaches in form the horizontal beam. Similarly in a given arch the errors are least at the apex where the axis is horizontal, and greatest at the abutments.

The end tangents shown in Figs. 4 and 8 evidently give the lines of action of the abutment reactions for the assumed system of loading.

The abutments are assumed to be inelastic and rigid.

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COAL AND THE LOCOMOTIVE.

GEORGE S. HODGINS (S.P.S., 1881).

Managing Editor, Railway and Locomotive Engineering.

It has been poetically said that coal is but the imprisoned sunbeams of the past, and although this may not be literally correct, yet it is a statement which embodies something of truth. Geological research has established the vegetable origin of coal, and the original plants, from the remains of which our coal was formed, drew their substance from the luxuriant soil of that far-distant epoch in which they lived. They separated out carbon and liberated oxygen under the genial influence of the sunshine of the very remote past. The predominant feature of the process here alluded to, was the chemical transformation from soil and air, under the sun's beams and by reason of the heat derived from that source.

George S. Hodgins,
Managing Editor, Railway and Locomotive Engineering.

Speaking of the Palaeozoic age and of the vegetable forms from which our coal is derived, Hugh Miller says, "In no other age did the world ever witness such a flora; * * * A rank and luxurious herbage cumbered every foot-breadth of dank and steaming soil, and even to distant planets, our earth must have shone through the enveloping clouds with a green and delicate ray." The growth of the plant was then for the most part a chemical process; a separation of elements and a union of others. For our purpose it may be summarized as the separation of the oxygen from the carbon and from the hydro-carbons of the plant, and the long burial of the fallen forests did not disturb these conditions as established when the plant lived. The solar energy effected the chemical changes which are reversed when coal is burned to-day.

Energy has been defined as the ability to do work, and energy may be present in the active or in the passive form—it may be potential or it may be kinetic. The passive or potential form can be seen when the hammer of a pile-driver is raised aloft, and hangs motionless and inert at the top of the guides. The attraction of gravity acts upon it, but until the detent is thrown out, the hammer cannot do work. It has, however, the potential energy of position with reference to the pile below. So it is with coal. It has not to be endowed with its energy by mechanical means like the hammer of the pile-driver. It possesses, by virtue of the solar energy of a by-gone age, the potential energy of chemical separation, and awaits only the presence of appropriate conditions (as the hammer waits for the detent) to burst into flame, and give back, by the union of the long separated oxygen and carbon, the energy stored up in its substance in the days when the earth was young.

This coal, heaped upon the tender of a locomotive and containing potentially the slowly accumulated energy of an era when mankind did not exist, yet finds the necessary temperature conditions, for liberating its stored up energy when thrown into the firebox. Here in the flame-storm above the white-hot fuel, the concentrated effects of solar energy are given off in the form of radiant heat and glowing gas which beat against the side and back sheets of the firebox, strikes up against the crown sheet, and rush against the tube sheet and through the flues. The steel plates of the firebox quickly transmit the radiant vibrations—this mode of molecular motion which we call heat, and if one may so say, these vibrations stream through the plates and out into the mass of water in the boiler.

Here the molecular agitation set up in the plates communicates itself to the water, and so intense are these heat vibrations, that the water ceases to retain the liquid form. Its particles are moved about with such exceeding rapidity that they are compelled to assume the gaseous state in order to give scope and freedom to the enormously rapid motion which they are compelled to adopt. Thus is formed what we call steam. The gaseous form of matter demands greater space for the swing and sway of its atoms, than is required in the liquid state. This demand for increased space, in a confined vessel like a boiler, produces a violent action of the particles, with more frequent and more powerful collisions between each particle. This phenomenon, we recognize as pressure. It therefore becomes apparent that the sun's action, directed upon the plant life of this earth, at a period so remote that the mind cannot grasp it, has waited through many ages to be so liberated and so employed, as to produce for us, what we prosaically describe as steam under pressure.

The opening of the locomotive throttle valve allows steam under pressure to flow through the dry pipe, down the branch pipes to the steam chests and thence to the cylinders. Here the vibratory action, deadened somewhat by hammering upon the walls and passages it has encountered and traversed, is a little less active, and we speak of it as having slightly cooled. Nevertheless, it continues a bombardment on piston and cylinder cover, and on the cylinder walls, as the vibrating particles of steam dash hither and thither in their endeavor to expand or run the full extent of their normal excursions. The fixed cylinder-cover remains unmoved, save that its particles imbibe the vibrations of the steam particles and so grows hot. The piston, however, capable of molar motion, is subjected to the myriad blows of the dancing steam particles and the piston gives way and slowly recedes before the gaseous onslaught of a billion atoms.

The piston moves back as a whole, though its particles are agitated like those of the cylinder cover, and the moving piston concentrates its action on the piston-rod. The rod forces the crosshead to move backward and this in turn communicates its motion to the connecting rod of the engine, and this being fastened to the crank-pin pushes it backward on the lower half of its course; the driving wheel revolves, and the engine moves ahead.

Here the curious phenomenon of the push on the crank-pin on its lower half-circuit, causing a forward motion of the engine, makes its appearance. Ordinarily if an object is pushed in any given direction, it moves in that direction, yet here we have a well-defined backward motion of the crank-pin producing a forward movement of the engine. The crank-pin is pushed backward on the lower half of its course and if this push could be given by a squad of men standing on the ground, the engine would move backward and not forward as we know it does. The reason why the engine moves forward when the crank-pin below the axle, is pushed backward by the agency of steam can be explained by a little alteration of the mechanism.

If the "big end" of the connecting rod was uncoupled from the crank-pin and placed so that it would rest against one edge of a tie on the track, the backward push of the steam on the piston would force the crosshead back, and the engine would go ahead. It would then be very evident that the connecting rod itself, or indeed the piston and crosshead, did not move at all, and the question arises from whence comes the motion of the engine, for it undoubtedly moves forward? We have now to return to a consideration of the bombarding action of the particles of steam in the cylinders. The bombardment of steam particles took place not only on the piston but on the walls of the cylinder and on the front cover. This incidentally shows that the pressure of steam acts equally in all directions. As the piston is held stationary by the connecting-rod with big end against the tie, the pressure of steam acting on the front cover moves it ahead. The cover being rigidly connected to the cylinder, and the cylinder being bolted to the frame; the cover, cylinder and frame together move forward, and as it were, draw the cylinder over the piston, and the forward movement of the frame carries forward the driving axle-box, and the wheel rolls forward. In this case the engine would only move forward a distance equal to the stroke.

When the connecting rod is attached to the crank-pin in the usual way and the pin acted upon by the backward pressure of the connecting rod, the wheel becomes practically a lever. of the second class, where the fulcrum is at the point of contact of wheel and rail, the power is applied at the axle box, and the resistance is at the crank-pin. The arm of the power is the distance from the axle-box to the rail, and the arm of the resistance is from the crank-pin to the rail. The power and the resistance being equal the greater length of the power arm causes it to predominate and compel the engine to go ahead. In this case the fulcrum constantly shifts, a new lever being, as it were, formed momentarily. The engine will now move a distance equal to the half circumference of the wheel.

As soon as the crank-pin comes above the centre of the wheel and enters upon its course above the axle, the piston is pulled forward and the back cylinder head and the frame are thrust back. The wheel again becomes a lever of the second-class with fulcrum at the rail, power applied to the pin, and the resistance at the axle. The leverage being now in favor of the pin by reason of its greater distance from the rail, than that from axle to rail, the force on the longer arm of the power prevails, and the engine continues to move forward. In the former case we spoke of the power being applied at the axle, and the resistance at the pin, when on its lower half circuit, in order to maintain the idea of the power producing the result observed. In this case with pin on its upper half circuit, we speak of the power being applied to it and the resistance as applied at the axle, for the same reason. In these two examples, for sake of uniformity, the arm of the power is in each case, taken as greater than that of the resistance. The predominence of the power, when viewed in this light, is apparent.

When examining the Stephenson link motion and D-slide valve of an ordinary 4-4-0 type of locomotive, one might be inclined to enquire why an engine starts in a predetermined direction from, say, the forward dead centre. If, for example, the right-hand piston is at the beginning of its backward stroke, and the reverse lever is in the extreme forward notch, the slide valve will be found to be open, the amount of full-gear lead, say 1-8 of an inch. If the reverse lever is moved backward to the centre of the quadrant, the valve opens the port further, until it reaches its mid-gear lead position. This is greater than the full-gear lead. If the motion of the reverse lever is proceeded with to the back notch, the valve moves to its full-gear lead position, which is, other things being equal, 1-8 of an inch. The question is, if steam be admitted to the cylinder under these conditions, which way will the engine move? Valve and piston are in the same position with reverse lever full forward or full back.

The obvious answer is that if we had only one side of the locomotive to deal with we might not make a very satisfactory start. The point, however, to remember is that if the reverse lever was in full forward gear and the engine attempted to go backward the small lead opening would be very quickly closed, but if the engine elected to go forward, the lead opening would be increased very promptly. At the time the right side of the engine is in full gear ahead, the left side of the engine, having its crank-pin set a quarter turn behind the right pin, is on the top quarter and the left slide valve is open so that steam can only enter the left cylinder behind the piston. Under these circumstances the engine can only go forward. The slightest motion in that direction places the right crank-pin below the centre and the engine moves ahead as a natural consequence.

We have, up to this point, endeavored to trace, though in a somewhat disjointed way, the present-day action of the long-gone-by power of the sun, until it re-appears in the motion of a modern locomotive. We have seen how the carbon and oxygen, united again in the firebox, gave back as heat, the energy which had originally been expended to separate them, and that the potential energy resident in the coal was not destroyed through the lapse of time. The accumulation of this potential energy by the plants was slow and gradual. Each one germinated, grew, waxed great and fell. Myriads of trees followed in the tardy process and were at length overthrown. The submerging, burying, solidifying of the forests required a period of time to which recorded history is as but yesterday. In the slow march of the years they were crushed down and built together into what we call coal. This age-long process has stored up for us, unused, the energy we now employ with prodigality as the spendthrifts of the ages. That a man may travel swiftly from Toronto to Hamilton there has been drawn from the storehouse of nature a supply of the once radiant energy of the sun, slowly gathered by plant life through long stretches of a distant past, and it is faithfully given back in the form of motion. The sun-god is still the power that speeds our trains over the iron way.

ENGINEERING IN CANADA.

WALTER J. FRANCIS, M.C.Soc.C.E., M.A.Soc.C.E.

Canadian Correspondent, The Engineer, (London),

It has been said that there is nothing new under the sun. Whatever there may have been in the untold ages of the past it is certain that for a score of centuries the human race did without countless things that to-day are considered necessities. From the days of Nebuchadnezzar, King of Babylon, to the time of George IV of England, and for even a longer period we did pretty much the same things in the same way, and the trifling changes made were due to the influence of climate more than to any other cause. The battles depended largely on the work of the individual soldiers in hand-to-hand encounter. Horses and men provided the sole means of transportation and communication by land. The only source of power in nature that was applied to the use and convenience of man was the wind —to grind corn and to propel ships. Nevertheless it was during these years that literature, architecture and art reached perfection so great that they stand to-day the masterpieces of the world, the examples which our most ardent students seek to copy, and the pride of the most cultured and scholarly.

The remarkable skill attained by the masons in pyramid construction, in the building of temples and, later, in cathedrals may account in some measure for the noteworthy accomplishments of the Romans in waterworks and roadmaking two thousand years ago, all being work in stone and consequently somewhat related in character.

It remained for the nineteenth century, however, to make advances along other lines that have revolutionized the world, advances which in effect may yet surpass the most sanguine dreams of the optimistic prophet. To-day people do things in a matter-of-fact way that would have been considered impossible fifty years ago. Who can foretell for ten years, say, what will be the developments in aerial navigation, in electricity with its countless interests, in chemistry or in surgery? With one exception surgery has advanced more than any other branch of learning in these latter days. That exception is engineering. Mankind must thank engineering for converting luxuries into necessities. Engineering has given the world its factories, its telegraphs, its steamships and its railroads. Even architecture, in spite of her ancient dignity, must acknowledge that her devotees are enabled to cope with the building problems of the day because engineering has produced the tall framework of steel and of reinforced concrete. Surgery, for whose youthful vigor the discovery of anaesthetics is responsible, may yet resort to electricity to render her subjects insensible to pain if one may judge of the articles in the current magazines. Our universities, so long sacred to classics and mathematics, are now unable to accommodate the young men who throng there to study applied science.

Walter J. Francis, C.E.,
The Engineer, (London).

It would be difficult indeed to eliminate the engineer from the world problems of to-day. He it is who develops the mining and produces the steel that spans our rivers, that forms a wonderful grillwork over our continents, that makes possible on our oceans the multitude of floating fortresses and cities, and that constitutes the myriad of machines which by their ingenuity compel us to stand in awe and admiration. He it is who harnesses the Niagaras of the world to provide us transportation, to transform the night of our cities into noonday, and to turn the wheels of commerce. The engineer has developed the details of sanitation and has thus bestowed upon mankind one of the greatest of blessings. Take from us the telegraph, the telephone and the wireless; take from us the typewriter, the talking-machine, the bicycle and the automobile, and we shall appreciate a little more fully some of the efforts of the engineer. The four words which comprehend "engineering" more completely than any others perhaps are power, manufacturing, communication and transportation. These four words embrace a very large part of the civilization of the present time. The greatest of these is transportation.

The charms of Canada, fairest daughter of the Mistress of the Seas, have naturally not been lost on the engineer. The growth of the two has been contemporaneous. Let us for a short time consider what has already been done, after which some remarks pertaining to the future of engineering in Canada may not be out of place.

It is not many years ago that Canada was described in almost the same words by which the schoolboy was taught to define a line—length without breadth. The land area bounded by the Atlantic and the Pacific, and lying between the 49th parallel and the North Pole, is very great; but most of it is still ruled by the unfettered hand of Nature, only a comparatively narrow strip along the southern boundary being settled and devoted to cultivation. The Maritime Provinces being accessible by sea from the old land were the first to be populated. The navigators continuing up the mighty St. Lawrence are responsible for the settlement of Quebec and the old part of Ontario. The needs of the district were not great but they taxed the engineering and financial resources to their utmost in providing the railways which now constitute a considerable part of the Grand Trunk System, and the artificial waterways that were constructed to overcome the obstructions in navigation in the Niagara River and along the St. Lawrence. The earliest noteworthy achievements in bridge building were the Victoria Tubular Bridge, built by Stevenson & Ross in 1859 over the St. Lawrence at Montreal, and the Suspension Bridge at Niagara built about the same time by Roebling. The opening up of Manitoba in the early seventies marked the first progress westward. The great Northwest was a desert littered with buffalo bones.

The wheat fields were as yet undreamed of. Fort Garry, by which name Winnipeg was first known, was a small village and Hudson Bay Company's post. Then came the building of the first transcontinental railway, the greatest railway problem the engineer had yet been called upon to solve. How well it was done has been amply proved by its subsequent use. To the construction of the Canadian Pacific Railway Canada owes the colonization of the West. The settlers poured in, the wheat fields were developed and Nature assisted by the farmer provides a volume of freight that taxes the facilities of some of the largest carriers in the world. The signpost of every new railway station is a grain elevator or group of them. In recent years we have seen the phenomenal development of the Canadian Northern, the Mackenzie and Mann system, itself now almost a transcontinental system. Within the next five years a third transcontinental line, the Grand Trunk Pacific, will have been completed, which will materially widen the narrow strip of settlement by opening up a parallel zone of wild country on the north. Surveys for new branch lines are extending in every direction from the main systems. The transportation problem becomes greater. Canada is a country of distances. Her geography necessitates the development of her transportation routes along east and west lines. The fact of having a complete railway system across the continent renders it practicable to operate a line of carriers on the ocean at either end, as the C. P. R. have done in their Atlantic and Pacific lines of steamships. These railways with their ever-growing branches are very fully occupied in transporting the wheat from the great West to the ports on the Pacific, to the head of the Great Lakes or to the port of Montreal.

The period of development of the western prairies has also seen the improvements to navigation in the great St. Lawrence route. About ten years ago the Soulanges Canal, one of the artificial links in this immense chain of navigation, was completed and stands as a masterpiece of 15-foot canal construction. The never-ceasing procession of freight boats passing day and night in navigation season through the magnificent locks on the St. Mary River at Sault Ste. Marie represents the largest tonnage passing through any canal in existence. The River St. Lawrence, navigated by ocean vessels to the port of Montreal, 1,000 miles inland, has been improved so that there is a lighted and buoyed channel at least 450 feet wide, with a minimum depth of 30 feet at extreme low water. Three years ago a 35-foot channel was commenced by the Department of Marine and Fisheries from Montreal to the sea.

During the same period of western progression the carrying capacity of the railways to compete in some measure with the waterways has increased tremendously, necessitating heavier rails, bridges and rolling stock. The increased traffic has compelled the railway companies to drive two tunnels under the water route, one at Sarnia and the other at Detroit, the former having been operated electrically since the summer of 1908. The historic Victoria tubular bridge has been rebuilt into a modern steel through bridge, and the well-known Niagara Suspension has given place to a magnificent steel arch. All over the country the bridges have been rebuilt, the wooden ones being replaced by steel, and the lighter steel structures by heavier ones. Many interesting and important examples of the bridge-builder's art of every type have been erected throughout the Dominion.

Naturally adequate terminal facilities became necessary and as a result we see the immense elevators at Port Arthur and Fort William and at other points on the Great Lakes. The port of Montreal, which at present can be used for navigation purposes only seven months of the year through adverse climatic conditions, has developed until it stands to-day, according to the statement of the president of the Board of Harbor Commissioners of Montreal, third in handling capacity per month of all British ports.

While the West has been developing and expanding, the population of the East has grown with remarkable strides. Of the Ontario peninsula this is particularly true, the inhabitants having settled down to highly developed agriculture and fruit growing. Villages and towns are thriving everywhere. The cities have grown with great rapidity, due in a great measure to the evolution of electric traction. Twenty years ago the bob-tailed horse-car running on a single track was a not unfamiliar sight in our cities. To-day sixty-foot electric cars on a two-minute schedule are incapable of handling the passenger traffic in the cities, the streets are congested with traffic, and elevated and underground lines are talked of. Montreal boasts a population of half a million and Toronto 400,000.

The application of electricity to modern needs has played a most important part in the upbuilding of the cities and in manufacturing. In older Ontario electric lines join many of the towns and villages together and bring the city markets within easy reach. The cheap production of electric current has meant that practically all the waterfalls in the inhabited districts have been utilized, and it may be said that every community of importance in the Dominion has its own electric light even at the comparatively greater expense of steam production. Coal occurs in Canada only in the extreme East and in the Rockies, leaving the great middle distance to depend on fuel transported great distances or on water-power.

The most important hydro-electric developments of Canada are of course at Niagara, where it is estimated 5,000,000 continuous electrical horse-power can be produced. Of this about one-tenth will be utilized when the stations now running are fully equipped. Four stations on the Canadian side can produce about 450,000 electrical horse-power. Of this quantity the portion now being taken up by the Ontario Government as distributors, acting as the Ontario Hydro-Electric Commission, will be transmitted at 110,000 volts over the whole of the Ontario peninsula distances up to two hundred miles. The construction of these high-voltage lines is now proceeding and is near completion. Already Niagara power operates the electric street cars at Toronto, 80 miles distant.

Throughout the populated parts of the country, excepting perhaps in the extreme east where coal abounds, there are hydro-electric developments. Near Vancouver the mountain streams are harnessed. At Nelson the Kootenay River furnishes 20,000 horse-power for the mining of the district. Outside of Winnipeg the Winnipeg River provides over 20,000 horse-power for the city. At Sault Ste. Marie about 25,000 horse-power is used, chiefly for industrial works. The city of Montreal uses for light, heat and power from 30,000 to 53,000 horse-power developed at Lachine, Chambly and Shawinigan. Near the city of Ottawa about 35,000 horse-power is developed for civic use and for manufacturing. In addition to these there are a great many smaller plants in operation and under construction.

The mining interests have also been of importance in developing the country. The coal mines of Nova Scotia, and of the Rocky Mountains, as well as the lignite of Alberta must be mentioned. The gold of British Columbia and the Yukon likewise had its effect. The silver fields of Cobalt and the nickel deposits of Sudbury are known the world over.

In education what do we find? Thirty years ago McGill University had less than fifty graduates in engineering as a result of a course established twenty-five years previously. At that time the Toike Oikes had not begun to exist. Now McGill has practically a thousand graduates in applied science. Less than thirty years ago the first graduate in engineering at Toronto left the college halls. Now they leave by the hundred each year and the University of Toronto claims over a thousand engineering graduates. From the Royal Military College at Kingston each year about thirty young men enter practical life with a training in civil and military courses. The universities of the other provinces also have engineering faculties, and the Canadian graduates in engineering now number considerably over two thousand.

The engineering work of the future in Canada is great. Development along present lines of the art means much municipal work, power development and transportation. Before many years Canada will have a number of very large cities. Montreal, Toronto, Port Arthur, Winnipeg, Edmonton, Vancouver and Prince Rupert will be very important centres of population and distribution, presenting all the problems in water supply, sewage disposal, passenger and freight handling, and civic work. In addition to these there will be an immense number of smaller centres. Civilization will spread gradually northward. The

Peace River country will be thrown open to settlers at a very early period. The untold wealth of the Rockies will be available. The water-powers adjacent to the new settlements will all be utilized. The older part of Ontario will become a manufacturing district by the use of the white coal from Niagara and the Ottawa. The important rapids on the St. Lawrence will be developed for power and manufacturing purposes. The practically unknown district of northern Quebec with its mineral and timber wealth and unlimited water-powers only awaits the arrival of men and money. The railways will increase their branches everywhere. A new route will be created to Europe by joining the Winnipeg district with Hudson Bay—indeed, part of the money for the construction was voted at the present session of Parliament. The waterways will be materially improved. Deeper river and lake navigation will be provided between Montreal and Port Arthur. The Georgian Bay Canal, being the canalization of natural rivers and lakes along the Ottawa from Montreal to Georgian Bay, will surely be constructed in the near future. The railways will be operated largely by electricity instead of by steam. The ocean navigation to Montreal will be in use the whole year round by the aid of ice breakers operating between Quebec and the Canadian metropolis. All this means highly developed terminal facilities, and a quantity of rolling stock and machinery that is difficult to comprehend.

What of the future along lines not yet fully developed? It does not require any great flights of fancy to locate regular lines of airships of some type. The monorail railway is undoubtedly past the experimental stage. The future is more likely to be marked by development and improvement rather than by fundamental invention. Someone has said that the only thing man has ever invented is the wheel. Every other mechanical element he has used he has copied in some form or other from nature. He is an imitator and improver. In the latter years he is developing himself in that way. He may shortly discover that his electric wires are quite unnecessary, and that he makes his machines too complicated. He already knows they are extremely wasteful, that he obtains in his steam plants, for instance, only about 5 per cent. of the heat value of the coal he burns and wastes the other 95 per cent. New sources of power may be discovered. In thirty years hence the people may respect our limited scientific knowledge as little as we do that of our forefathers of fifty years ago. Time only will tell.

There is one other phase of the subject of engineering that I have not referred to. We have spoken in a general way of what the engineer has done and may yet accomplish. What he has not succeeded in doing is well illustrated by a story told to a university class in engineering economics by their honorary lecturer, who by the way is the first Toronto graduate in mechanical engineering. Certain Simians having a little more brains than their fellows used sticks with which to knock down their cocoanuts. They were the first engineers. Another Simian having still more grey matter congratulated them on their ability to select suitable sticks. Impelled by the flattery they went for more sticks, leaving him to knock down the nuts. He was the first financier. We have continued to gather the sticks, leaving the financiers to carry on their work. Maybe we shall yet learn enough to knock down the nuts for ourselves. Time will tell.

COST OF SEWER, MUSKOKA, ONT.

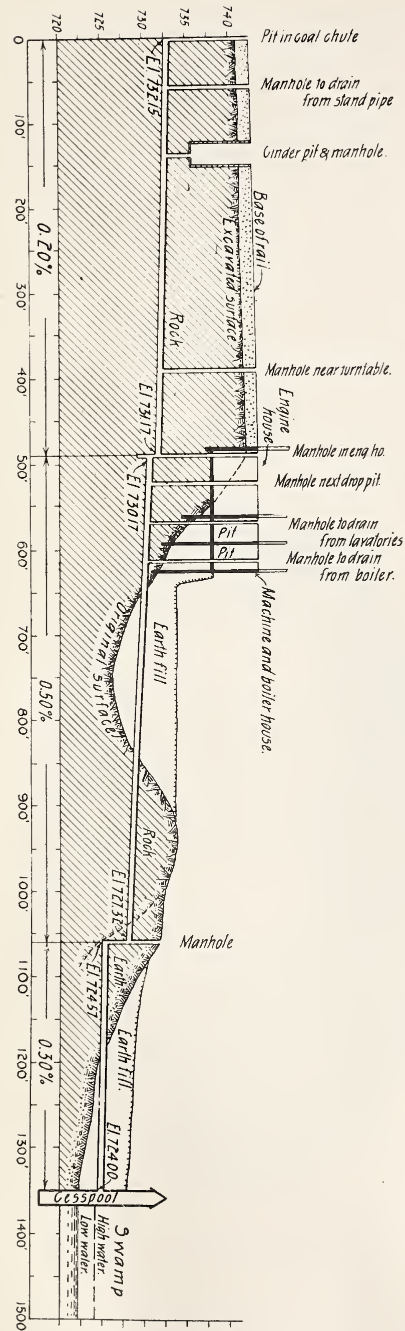
E. A. JAMES, B.A.Sc., A.M.C.Soc.C.E.

In September, 1908, the Canadian Pacific Railway opened their Toronto-Sudbury line. This line, two hundred and sixty miles long, runs from Toronto in a northly direction, leaving the Owen Sound branch at Bolton Junction, it passes to the west side of Lake Simcoe and crosses the G.T.R. Collingwood branch on the level at Utopia; the Penetang branch on the level near Coldwell Junction and the Midland branch on the level east of Coldwater. The line continues north, west of Muskoka Lakes, crossing over-head the G.T.R. (Canada Atlantic Division) near Parry Sound, and joining the main line of the C.P.R. at Romford Junction, a station seven miles west of Sudbury.

At Muskoka, one hundred and thirty-one miles north of Toronto, is situated the only division point on this line. At present it consists of a railway division yard, a small village of a dozen houses, railway station, round-house, machine shop, coal chute, etc., and a railway-owned-and-operated electric light plant and waterworks system.

E. A. James, B.A Sc., A.M.C., Soc. C.E.
Managing Editor, Canadian Engineer.

In 1907 this district was uninhabited forest and when the new townsite was laid out under Mr. F. S. Darling, M. Can. Soc. C.E. Division Engineer, in charge of construction, the first work to follow the grading was the construction of a sewer.



Surveys showed that the most suitable sewer to build would average ten feet deep through some seven hundred feet of Laurentian granite.

The work of digging the sewer was ordered to go ahead in the middle of July, 1907, and as the erection of necessary buildings for the yards could not be proceeded with until the sewer was completed, because of the blasting, the work was opened up in four places at once and four gangs kept busy until the work was nearly completed.

Continued dry weather made it possible to work to grade at the upper end of the sewer before the lower end was open so that work was commenced simultaneously at stations 0, 6, 8+50 and 11+50 at the same time.

The material from station 8+50 to 11+50 was wasted between stations 11+50 and 15+50, and from station 8+50 to 7, thus making this haul very short but the material from station 0 to station 6 had to be hauled about 1,500 feet, i.e., to the south end of the yards.

This material was broken by dynamite in the trench, mucked into skips and hoisted by horse-derricks upon horse-cars which ran on 30-pound rails.

The profile will show fairly well that there was about 550 feet of sewer 9 feet deep in granite rock and 350 feet about averaging 4 feet deep with a stripping of 2 feet of earth.

A close measurement of the work gave the following quantities :

Common excavation	950 cu. yds.
Loose rock	30 cu. yds.
Solid rock	1,850 cu. yds.

From the following calculations the common excavation and loose rock are eliminated as the cost of that work was kept separate.

The complete cost for 1,850 cubic yards of solid rock was as follows:

			Per cu. yd.
Superintending—			
Walking boss, at 60c per hour	$222.45	or	12.0c
Clerk and timekeeper, at 37½c per hour	158.60	or	8.5c
Foreman, at 45c per hour	608.15	or	32.8c
Total for superintending per cu. yd.			53.3c
Labor—Mucking, loading, hauling and dumping—			
Laborers, at 20c per hour	$2,877.00	or	$1.555
Teamsters, at 21c per hour	499.70	or	.270
Teams, at 40c per hour	1,010.60	or	.545
Cars, at 5c per hour	117.00	or	.063
Carts, at 5c per hour	65.50	or	.035
Derricks and power, at 15c per hour	175.50	or	.095
Handy men, at 27½c per hour	125.15	or	.067
Total for labor per cu. yd.			$2.630
Drilling rock—			
Foot drilling, at 30c per ft.	$1,245.00	or	0.673
Sharpening drills, at 27½c per hour	250.80	or	.135
Nippers, at 17½c per hour	382.20	or	.206
Coal, at $10 per ton	29.00	or	.157
For drilling per cu. yd.			$1.171
Explosives—			
Electric fuses			$ 95.95
Caps and fuses			23.20
Batteries, rent			38.00
60% dynamite, at $10 per box			1,020.00
Or 0.636 per cubic yard.			$1,117.15

Making a total of $4.97 per cubic yard.

To this must be added an amount for the depreciation of plant, in this case $930. This included broken and wasted material and drill steel sharpened away.

This was equivalent to 50 cents per cubic yard and made a grand total of $5.47 per cubic yard. When it is remembered that it was rock work where the wear and tear upon plant was great this amount is not unreasonable.

This price, i.e., $5.47 per cubic yard for solid rock, is high, but the trench was for 18-inch pipe; it was not wise to use large shots and the amount of drilling, i.e., one foot for 4½ cubic yards, was excessive. The price is not high for trench work in rock.

SAVING WASTE IN MANUFACTURING—A FIELD OF WORK IN WHICH THE TECHNICAL GRADUATE MIGHT WELL LOOK FOR A FUTURE.

J. C. ARMER, B.A.Sc.

Editor of the Canadian Manufacturer.

The technical graduate when seeking a job usually adopts the line of least resistance. Upon graduating few of us can afford to twirl our thumbs until our chosen job turns up. We usually are inclined to take the first good position that we can get. Circumstances usually have more to do with the character of our first job than our own plans and aspirations; and our first job has more to do with our second job than any other influence.

This is why we see so many technical graduates in certain lines of industrial life and so few in certain others. It is to the advantage of the technical graduate to have as many fields of industrial life open to him as possible — to have many lines of little resistance and few of great resistance.

J. C. Armer, B. A.Sc.,
Editor, "Canadian Manufacturer."

The Technical Graduate and the Manufacturing Industry—There will be in the future a closer bond of union than has been in the past.

The manufacturing industry in Canada (except what might be termed the purely engineering part) has been, for the most part, behind a closed door as far as the technical graduate is concerned. There is more than one reason for this; and probably every man one might consult on either side of the door would give a different reason, and most of these reasons might be correct. Being a technical graduate myself, and also having been brought into close touch with the manufacturing industry during the past six or seven years in a capacity which led me to study this very question somewhat, I realize a few of the conditions that prevent the door opening wider. Of course everything centres more or less around the fact that neither side fully realizes the possibilities of the other. That is the root of the evil.

I believe that the co-operative engineering course, that has been established at the University of Cincinnati, in which the student spends alternate weeks in the college and in different factories and shops in the city, is a part of the solution of this problem. The Faculty of Applied Science, I think, will come to it sooner or later. I know "the powers that be" are watching the experiment in Cincinnati with very keen interest.

In this connection the Executive of the Engineering Society are to be congratulated upon the idea which they carried out at their annual dinner in January; but it is to be deplored that the Board of Governors at the same time let slip such an excellent opportunity of establishing a better understanding by the manufacturers of the work the Faculty of Applied Science is doing through the new mechanical laboratory.

That there is a broad field of work in the manufacturing industry for the technical graduate need not be doubted. A few manufacturers in Canada are realizing it, and are employing technically trained men in positions heretofore held only by men who had spent the better part of their life at the work. The object of this article is not, however, to discuss this subject in general, but to bring to the reader's attention one line of work in the manufacturing industry for which a technical graduate—a student—a man who is trained to bring together cause and effect—is eminently fitted.

The "Saving of Waste in Manufacturing" is a field of work eminently fitted for the technical graduate.

This line of work is the "Saving of Waste." Not a very high sounding title, is it? "Quite beneath the aspirations of an ambitious technical man," some may exclaim; "he wants to construct—to build—not to save;" but before the reader jumps to a hasty conclusion, let him study the trend of modern industry—let him put his fingers on the pulse of modern manufacturing—and he will realize that the "Saving of Waste" is to be the most absorbing science on this continent at no very distant date.

Every one is more or less familiar with the remarkable strides which have been made of late years in the saving of waste in materials, but very few realize the waste which is bound up in the human element — the waste due to the inefficiency of workers. The technical student puts in most of his time studying materials, so that he can classify them, select them to advantage and get the greatest efficiency from them; and practically no time is given to the study of human nature—we have no data collected, no formulas with which to work; yet the real saving of waste in manufacturing has to do more largely with the human element than with the material or the machine.

Evidence of the possibilities there are of increasing the efficiency of workmen in the manufacturing industry.

At one time I operated a planer beside a red-headed Irishman in a certain railway machine shop. This Irishman was running a big slotter. Very many of his antics were very interesting and amusing, but the one that interested me most was his unfailing practice of first removing his overalls, and then stopping his machine, from fifteen to twenty minutes before time. That fifteen or twenty minutes he spent either huddled over his work —to give the foreman the impression that he was adjusting it— or else dodging around his machine to keep out of sight altogether. I wager he did more work in that time than in any other hour and a half. To my queries as to why he shut off his machine so much before time, he would answer: "Well, by the time you have worked as long in the shop as I have, you too will want to get out of as much work as you can." To take off overalls and otherwise prepare for a hasty exit when the whistle blew was natural, although possibly not laudable; but to work extra hard on his employer's time that he might not do the work for which he was paid, even when that work consisted of sitting on a box watching his machine cut the metal, is an exhibit of what the human element may mean in shop inefficiency.

Mr. F. W. Taylor, the author of that world-known paper, "The Art of Cutting Metals," presented to the American Society of Mechanical Engineers as a presidential address some few years ago, who has given more than twenty-five years to the scientific study of efficiency, says of the average workman's potential efficiency:

> "That the first-class man can do in most cases from two to four times as much as is done on the average is known to but few and is fully realized by those only who have made a thorough and scientific study of the possibilities of men. * * * It must be distinctly understood that in referring to possibilities, the writer does not mean what a first-class man can do on a spurt or when over-exerting himself, but what a good man can keep up for a long term of years without injury to his health, and become happier and thrive under."

The inefficiencies in the conduct of workmen which Mr. Taylor, and others such as Mr. Harrington Emerson, have found in a number of places are surprising and most significant. In the rough labor employed in the Bethlehem Steel Company's yards Mr. Taylor found an efficiency of only 28 per cent. Mr. Harrington Emerson determined an efficiency of only 18 per cent. in a gang of laborers excavating a foundation. He has found that the average railway repair shop shows an efficiency of only 50 per cent. He says that in the United States the total amount of preventable material and labor wastes and losses in railroad operation and maintenance approximates $300,000,000 annually. Harrington Emerson also says in one of his writings:

> "To the efficiency of a process or in the use of a material there is a clearly ascertainable maximum, and when it is exceeded the material gives way, as in the Quebec bridge; but to the efficiency of an individual there is no predeterminable limitation. In the passion for modern scientific accuracy much has been done to solve the lesser problem of efficiency in process or material, but the larger problem of individual efficiency has been almost wholly ignored."

In the face of this, and much more that a little investigation shows the student, does not this field of endeavor, "The Saving of Waste in Manufacturing," stand on as high a level as any other field open to technically trained men, and should not this practically untouched field in Canada appeal very strongly to a number of undergraduates and graduates of the Faculty of Applied Science!

What a few manufacturers in Canada are now doing in increasing the efficiency of their factories by the elimination of waste.

In Canada manufacturers are beginning to realize that immense amounts of money could be saved in materials and labor in their factories and plants; and efforts are being made in some places to effect these savings—the amount of the success depending upon the amount of good, hard study and good common sense put into the effort. I know of a stock room in a Toronto factory in which the manager increased the working efficiency 50 per cent. by a judicious handling of human nature, which, however, is a part of a well founded plan which extends over the entire factory. The manager had no data as to the increase of efficiency over the entire plant, but from figures available one might judge it would be 25 per cent.

The manager of a certain Toronto factory (the Canadian factory of the National Cash Register Co.) owing to a certain exigency was required to decrease the operating expenses of his factory by $12,000 per year, without interfering in any way with the quality of the product or the broad principles upon which the factory is operated. This factory manager was already doing what more than 75 per cent. of managers do in keeping down costs in the factory; and he did not think that he could cut out more waste to the tune of $12,000 per year. However, he called together his heads of departments, including purchasing agent, engineer and foremen, and put the problem straight to them. As a result of co-operation of all hands, this manager now has under way schemes which will save more than the $12,000 per year. This is an indication of what is possible in the saving of waste even when there appears to be no waste.

I might give other instances such as this; and they would all show the field there is for such work as this in Canada, and what openings there will be for the man who has made a thorough study of systems, organizations and human nature—theory and practice—the man who can go to the manufacturer for a job and in reply to the query, "What can you do?" say, "Well, I can increase the efficiency of your plant by 5 per cent. at least and possibly by 40 per cent."—of course in not quite such a bald manner. An answer such as that would certainly have more effect upon a manufacturer, one way or another, than an answer such as this: "Well, I can operate a planer, do some work on a lathe, and I think I understand Hirn's Analysis"—not meaning any disrespect to Hirn's Analysis.

What the technical graduate may expect in the way of remuneration in this field.

As to salary—the efficiency engineer in the United States who has accomplished things does not have to wear last year's hat, unless he wants to. From the nature of the work done it stands to reason that good salaries can be demanded. For instance, if in a factory employing 200 men at an average of $2.50 per day the individual efficiency were increased by 5 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{5}{100} = \$9{,}000^*$$

or if the efficiency were increased 40 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{40}{100} = \$72{,}000^*$$

The man who accomplished this could of course collect from it a salary that would look fairly large to the average engineer.

This field of work contains its share of necessary preparation, hard work, drudging, keen grasping of causes and effects, close study of present methods, a keen study any analysis of human nature, a continual collecting of data, etc., all this based upon a good sound technical training at college.

As to what the Faculty of Applied Science might do towards preparing a man for such a career, much might be said, but at the present moment one feels that it is bad form to suggest further burdens for the Faculty of Applied Science unless at the same time he comes prepared to pry open the treasure chest guarded by the governing powers, in which there may be a treasure and yet there may not.

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* This method of figuring the saving is not correct, but the results are near enough for illustrating the point.

THE ACTION OF FROST ON HYDRAULIC CEMENTS—CONCRETING DURING FREEZING WEATHER.

ALFRED E. UREN, B.A.Sc.
Editor Canadian Cement and Concrete Review

In Canada and the Northern American States, where the effect of frost during the winter season is a more serious question than it is in many European countries, numerous experiments and investigations have been made to determine the effect of freezing temperatures upon hydraulic cements. The writer has endeavored to outline in this article some of the more important investigations made by various authorities along this line, as well as to call attention to the more common methods employed in practice of mixing and placing concrete during low temperatures.

Alfred E. Uren, B.A.Sc.

While the conclusions of different experimenters are not in perfect accord, from practical experience as well as from laboratory investigations, it is now generally accepted that the ultimate effect of freezing of Portland cement concrete is to produce only a surface injury. While experiments have proven that the setting and hardening of Portland cement concrete is retarded by freezing, and the strength at short periods lowered, still the ultimate strength appears to be but slightly, if at all, affected. Mr. Sanford E. Thompson, consulting engineer, is authority for the statement that neither in practise nor research has he ever discovered a case where Portland cement concrete or mortar, laid with proper care, has suffered more than surface disintegration from the action of frost.

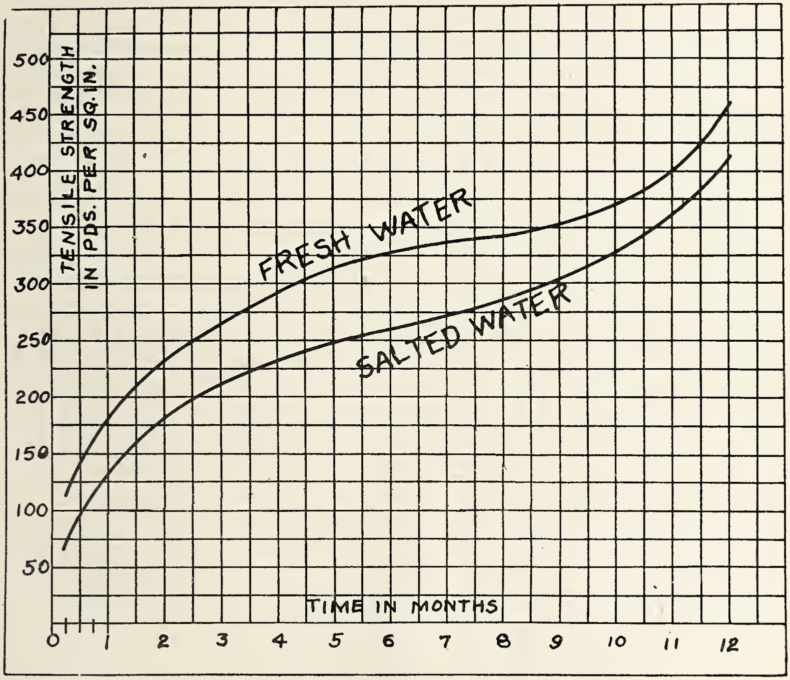
While authorities on the subject of concrete, in general, agree that concrete work should be avoided as far as possible during frosty weather, as it is much more difficult to mix satisfactorily and to place materials under these conditions, still if circumstances warrant this added expense, with proper precaution and careful inspection, mass concrete may be laid at almost any temperature. The proper precautions necessary to insure satisfactory results for work laid in freezing weather depend upon the class of work, heavy mass concrete not requiring the same care and protection as light reinforced construction. The subject, in so far as light work is concerned, is summed up in the words of Mr. W. J. Francis, consulting engineer, Montreal: (Paper read before the Canadian Cement and Concrete Association March, 1909.) "Do not erect light building work in reinforced concrete during freezing weather. If you are compelled to do so, be careful. It can be done but it means money and eternal vigilance."

A word of caution against the growing disregard of, and apparent indifference to, the importance of properly placing and protecting concrete work in freezing weather is not out of place. The practise of mixing, placing and caring for concrete work during winter weather in the same manner as in warm weather is, of course, to be condemned. The satisfactory results usually obtained during the winter months with Portland cement concrete serve as an incentive for increased activity and encouragement for carrying on concrete work under unfavorable weather conditions.

It is generally understood that concrete, frozen before the action of hardening has started, is not apt to be injured, if upon thawing, it is not again frozen until it has had a chance to harden sufficiently to withstand the action of subsequent freezing. The alternate freezing and thawing, which allow the intermittent action of hardening, are the conditions to be avoided. In laying concrete the surface freezes unless measures are taken to prevent it. It is well known that a thin crust, about one-sixteenth of an inch in thickness, is apt to scale off from granolithic or concrete pavements which have frozen before hardening. This leaves a rough instead of a trowled wearing surface. The effect upon concrete walls is sometimes similar.

As regards natural cements, they are particularly susceptible to serious injury from frost, especially by alternate freezing and thawing. Certain cases have been sighted where natural cement mortar has been laid in freezing weather with no serious results; there are, however, numerous examples where complete failure has been brought about. Mr. Sylvanis Thompson (see Concrete, Plain and Reinforced) has observed, that after several years, natural cement mortar was but slightly better than sand and gravel. These results were observed by him in the case of natural cement mortar laid during the comparatively warm winter of North Carolina, on days when the temperature was considerably above freezing at the time of laying, and also in the cold climate of Maine where the mortar froze as it left the trowel, without thawing before the spring season. Settlement of masonry when thawing is often a serious characteristic of natural cement. Occasionally tests are recorded in which natural cement mortars have after a time, attained full strength, in cases where they have been subjected to a uniformly cold temperature and then suddenly thawed. However, in view of the fact that there is some doubt on the subject, the investigations made are sufficient to warrant the use of a true Portland cement when frost is likely to occur during erection work, or before the mortar has thoroughly dried. Natural cements are but little used in Canada at the present time for construction work, nevertheless it is of interest to make these comparisons between the action of Natural and Portland cements.

Several methods are employed in practice to overcome effects produced by low temperatures. The following are those most commonly employed: (1) The addition of a chemical or chemicals that lower the freezing point of the water. (2) The application of heat to the aggregates. (3) Protection of work, by enclosure, etc. In the first instance, common salt (sodium chloride) is commonly used. Calcium chloride is sometimes used as experiments indicate that if used in quantities not exceeding 2 per cent. of the weight of the cement, it is an effective agent for lowering the freezing point of concrete. It should, however, be used with caution, since a larger quantity than this is likely to so hasten the set as to make the concrete difficult to handle. Other materials, such as alcohol, sugar and glycerine, have been employed in an experimental way. It has been found, however, that they have a tendency to lower the strength of the mortar. Specially prepared liquids and patented compounds have been placed on the market for the purpose of lowering the freezing point, in some instances with considerable success. These are usually dissolved in the water used for mixing. Salt is claimed by some to be detrimental to reinforced concrete, claiming that salt and air corrode steel and that even where steel is not present,



concrete is likely to become somewhat porous. These advocate mechanical means entirely where both moisture and heat should be provided.

As regards the percentage of salt to be added, authorities differ slightly. One method is to add to the water, one per cent. by weight of salt, for every degree Fahrenheit below the freezing point. One authority gives 8 pounds of salt per barrel of cement as sufficient, even in the coldest weather. Others recommend 1.06 pounds per cubic foot of cement. Ten pounds to every barrel of water used, is recommended by one authority.

An original method employed by some consists of adding sufficient salt to the water to give a 12 per cent. solution. A potato has a specific gravity of about 1.08. A 12 per cent. solution of salt and water has a specific gravity of 1.082, a solution which will float a potato. This method is sometimes employed in gauging the density of the salt solution. A 9 per cent. solution by weight of salt to water, was used in the construction of the New York Subway in 1903. On the Wachusett Dam, during the winter of 1902, four pounds of salt were used to each barrel of cement. For a 1 to 3 mortar this corresponds to about 2 per cent. of the weight of the water. Mr. Sanford E. Thompson has adopted the arbitrary rule of two pounds of salt to each bag of cement, to be used when the temperature is expected to fall several degrees below freezing, and if experience shows that this is not quite sufficient to prevent the frost catching the surfaces, three pounds of salt per bag of cement are to be used instead.

The accompanying curves plotted from experiments made by Mr. Chas. S. Gowen, extending up to one year (Proceedings American Society for Testing Materials, 1903, p. 393) show the effect, at laboratory temperature, of 10 per cent. of salt on a 1:3 Portland cement mortar, also that of fresh water.

Perhaps the more preferable method and one commonly employed, consists in mixing warm sand and stone with the cement and water, in such a manner as to bring the temperature of the entire mixture to about 75 degrees Fahr., protecting it from the air during the early stages of the setting. The water may be also heated. In the erection of a building for the Foster-Armstrong Co., Ltd., of Rochester, N.Y., the water was heated to about 90 degrees Fahr., and salt added in a proportion of about 1.06 pounds per cubic foot of Portland cement. The method of heating the water consisted of passing live steam through perforated pipes in storage tanks, and the sand and gravel were heated in the storage bins by means of steam pipes and hot air pipes. As each part of the building was constructed it was housed in by a temporary structure of timber and canvas, the open sides being enclosed by canvas curtains. The space enclosed by this housing was heated by coke fires and braziers, and by means of steam pipes from a central boiler, live steam being discharged into the spaces between the housing and the concrete.

The temperature in the enclosed spaces was kept at about 80 degrees Fahr., below the floors, and about 40 degrees Fahr. in the spaces between the top of the floor and its board covering.

Mr. J. H. Chubb, Assistant Inspecting Engineer Universal Portland Cement Co., Chicago (Bulletin No. 56, January, 1909) states that "Salt should be used only in plain concrete work, as its effect on reinforcing metal has not been established. Even when salt is used it is important that the aggregates be free from lumps of frozen material, as it is impossible to properly mix such materials. Approximately one per cent. by weight of salt to the weight of the water is required for each degree Fahrenheit below freezing, but more than ten per cent. of salt should not be considered safe and this amount is not effective for temperatures lower than twenty-two degrees Fahrenheit. The best method of concreting in freezing weather is to heat the materials and to protect the work until it has obtained sufficient strength to withstand the action of frost. Either the water, sand and water, or sand, stone and water should be heated. The cement is usually not heated. Heating the materials accelerates the rate of hardening, lengthens the time before the material becomes cold enough to freeze, and in temperatures but little below freezing will insure the hardening of the concrete before it can be damaged by freezing. For heavy mass work, thick walls, abutments, etc., it is not necessary to heat the stone except in exceptionally cold weather, but sand and water should be heated. If the forms are tight and made of heavy material, it will only be necessary to protect the top of the work; this may be done by covering with a canvas and running steam under it, or by covering with boards or paper and applying a covering of straw or manure. If such work is protected from freezing for several days it is sufficient, unless it has to be loaded immediately, but thin walls, light foundations, etc., should be protected on all sides in the manner pointed out above. For reinforced work it is necessary to heat all the materials but the cement, and the concrete should be hot when placed in the forms, and where the work must be placed into service as soon as possible, the only safe practice is to keep the surrounding temperature well above the freezing point until the work has thoroughly hardened. Concrete increases in strength but very slowly in cold weather, and for this reason forms should be left on as long as possible, and care taken not to load a structure too soon. Just how old the work should be before removing the forms and subjecting it to its load cannot be stated, as this will depend entirely upon how fast the concrete hardens. Careful inspection of the structure is necessary before removing the forms and applying the load, and it must be remembered that frozen concrete, which upon thawing has but little strength, closely resembles thoroughly hardened concrete in appearance, and when broken frequently shows a fracture through the aggregate. All classes of concrete work, with the exception of walks and pavements, may be constructed in freezing weather, but to insure satisfactory results proper precautions are necessary, which will entail an additional expense, depending upon the class of construction and importance of the work."

Engineering News (Vol. XLIX, No. 12) contains an article by Geo. W. Lee, where a combined water, sand and stone heater was used successfully. It was erected at a cost of fifty dollars and weighed about twelve hundred pounds. Considerable concrete work on the construction of Hurdman's Bridge, Ottawa, was carried on when the temperature was as low as 12 degrees below zero. In this instance the materials were partly heated, and partially protected with canvas cover after being deposited. A first-class concrete was produced. Engineering News (Vol. XLIX, No. 19) contains a description of the construction of a concrete dam at Chaudiere Falls, Province of Quebec. It was found necessary to construct a portion of this work during the winter months when the temperature ranged all the way to 20 degrees below zero.

The action of frost on Portland cement mortar and neat cement has been extensively investigated in an experimental way. A series of interesting experiments by Ernest R. Matthews, Borough Engineer of Bridlington, England (Volume XXXV, proceedings of the American Society of Civil Engineers) give in detail the action of frost on cement and cement mortar, together with other experiments on these materials. These investigations were made for the purpose of ascertaining, among other things, the effect of frost, and alternate frosts and thaw, on the tensile strength of cement and cement mortar when mixed with cold or warm water, also the temperature below which it is detrimental to mix Portland cement concrete. The cement used was manufactured by Robson's Cement Company of Hull, England, and conformed to British standard tests. These investigations led to the following conclusions:

(1) That light frost occurring 24 hours after the cement has been gauged (3° of frost, or thereabouts), is detrimental to freshly mixed Portland cement, but only for a short time, and that at the end of 28 days it has quite regained its normal strength. If the frost occurs immediately after the cement has been gauged, the effect is more detrimental, and would appear to be permanent. A minimum quantity of water should be added in frosty weather.

(2) That heavy frost (17° of frost, or thereabouts) has a most injurious effect (permanent) upon freshly mixed cement (neat), and cement mortar.

(3) That a light frost (3° of frost, or thereabouts) does not affect cement or cement mortar if it has attained two days' set previous to the occurrence of the frost.

(4) That the detrimental effect of light frost upon cement mortar (3 to 1) occurs more immediately than upon neat cement,

but that cement mortar recovers from the ill effects of frost more rapidly than neat cement. At the end of 14 days it has quite recovered.

(5) It would appear that it is detrimental to concrete to mix it when the temperature is below 29.3° F. (2.7° of frost), that being the freezing point of cement and concrete.

An extensive series of experiments conducted by Mr. Thomas F. Richardson at the Wachusett Dam in Massachusetts, extending up to one year, were sufficient to conclude that Portland cement mortar is not permanently injured by freezing. These experiments were conducted in the middle of the winter. Two bags of Portland cement were thoroughly mixed together and all the briquettes were made from cement taken from these bags. These experiments were carried on while the masonry work on the dam in question was in progress. The briquettes that were tested were made each week and submitted to the same conditions as the masonry, the moulds being placed in the open air and not in water, immediately after filling. At the same time briquettes were made that were kept in the laboratory. Those out of doors were exposed to temperatures as low as 9 degrees above zero during the first 24 hours, and some to temperatures as low as 12 degrees below zero during the first week. Salt ranging in quantity from 4 to 16 pounds per barrel of cement was used in most of the experiments (the average being about 3 per cent. by weight of water). These experiments indicated that 8 pounds of salt per barrel of cement is sufficient even in the coldest weather, that 4 pounds is very nearly as good but that 16 pounds does not seem to give quite as good results. The following table, which gives the average results of these experiments, shows the effect of frost upon the tensile strength of a 1 to 3 mortar mixture:

Briquettes Kept.	No. of Briquettes	Tensile Strength, lbs. per square inch.				
		7 Days	28 Days	3 Months	6 Months	1 Year
Water in Laboratory....	20	268	304	359	370	401
Air in Laboratory......	20	298	352	364	392	517
Out doors, below freezing	80	139	238	344	435	627

Table showing the effect of frost on the tensile strength of a 1: 3 mortar mixture.

During 1901, interesting and valuable experiments were conducted at the Watertown Arsenal, U.S.A., to ascertain the effect of low temperatures upon the strength of cements and cement mortars, the results of which are given herewith. For a complete description and results of these experiments see "Tests of Metals," U.S.A., 1901, page 530, from which these results were taken. A part of these experiments consisted of placing groups of cubes in a cold storage warehouse, where some of them were subjected to a temperature of 39° F. and some to a temperature of 0° F. Those subjected to the lowest temperature were mixed and moulded in a temperature below freezing. All cubes were subjected to the tabulated temperature as soon after mixing as practicable, and before being tested were kept at a temperature of 70° F. for the number of days indicated. Herewith are tabulated some of the results on cubes composed of a 1:1 Portland cement mortar, gauged with 16% water for the group subjected to 0° F., and 12% water for the other group.

EXPERIMENTS CONDUCTED AT THE WATERTOWN ARSENAL TO DEMONSTRATE THE EFFECT OF LOW TEMPERATURE UPON THE STRENGTH OF CEMENTS AND CEMENT MORTARS. THE AVERAGE COMPRESSIVE STRENGTH OF FIVE CUBES IS GIVEN IN POUNDS PER SQ. IN.

Days at 0° F.	Days at 70° F.	Strength.	Days at 0° F.	Days at 70° F.	Strength.	Days at 39° F.	Days at 70° F.	Strength
5	1	287	5	7	846	15	0	1710
14	1	321	14	7	1000	31	0	1960
21	1	337	21	7	1010	60	0	2460
31	1	383	31	7	981	15	7	2710
60	1	416	60	7	981	31	7	2720
90	1	497	90	7	1010	60	7	3270

The results of practice and experiment with cements exposed to frost lead to the following conclusions:

1. Most natural cements are completely ruined by freezing.
2. Frost expands natural cement masonry and settlement results with the thawing.
3. The ultimate strength of Portland cement in mortar or concrete is but slightly, if at all, affected by freezing, although its setting and hardening is retarded and its strength at short periods lowered.
4. Heating materials hastens setting and retards the action of frost.
5. Salt lowers the freezing point of water and does not appear to affect the ultimate strength of the concrete or mortar, if added in quantities up to ten or twelve per cent. of the weight of the water.
6. A thin scale is apt to crack from the surface of concrete walks, walls, etc., if frozen before the cement has hardened.
7. Concrete work, if possible, should be avoided in freezing weather because of the difficulty and expense of attaining perfect results.

RECENT ADVANCES IN ELECTRICITY.

CLARENCE E. BOTHWELL
Associate Editor Canadian Electrical News

Ninety years ago electricity was defined in an American text book as that property in bodies in virtue of which, when rubbed they attracted substances and emitted fire, and even as late as fifty years ago this might have represented the popular knowledge and conception of things electric. The slow evolution which has transpired is not unnatural and in dealing with electrical science, history has but repeated itself. Throughout all ages the progress of any change destined to be of world-wide importance has always been notoriously retarded. The disconnected theorem of the scientist must first be given to an unheeding public. Perhaps a few generations later these same principles are embodied, through the genius of the inventor, in a device which constitutes a distinct advance in commercial progress. The next step is to secure the adoption of the invention by a sceptical industrial public. In this sphere radical departure from methods of accepted procedure always have met with deep-rooted opposition, and at the best only a modification of the device in hand is accepted. Once, however, the confidence of the industrial world is obtained the appliance of meritorious value makes rapid strides.

We find that the fundamental principles of electricity were exploited by eminent physicists years before they were turned to commercial account, and the invention of electric machines received but scant attention until many years after their preliminary investigation and actual commercial establishment. Twenty-five years ago incandescent lamps were an advertised feature of industrial exhibitions and were considered a freak rather than a factor in the country's development. The changes within the last decade have indeed been wonderful. Electricity and progress are interchangeable synonyms and the world recognizes that mostly all recent accelerations of modern business conditions are the achievement of the electrical engineer.

In the operation of industrial establishments, electrical power is forcing recognition as an important factor. Its entrance to this field is not of long standing. First, came its use in an auxiliary capacity for the operation of special or isolated machines and gradually upon its merits it superceded other forms of power for factory operation. To commend it were many striking qualities: Its absolute cleanliness; its adaptability to the closer speed regulation of modern high-grade machines; acceleration of output, which the perfection of the high-speed motors made possible; the economy of space afforded in the system of power distribution over other more mechanical methods; its cheapness, where water power is available, compared to other methods of operation.

To enumerate the every-day uses of electricity, all of which have had their place in the world's industrial progress would entail a needless repetition. To mention the myriads of opportunities for its application would be impossible. Wireless telegraphy with its more or less widespread use is but in its infancy. Marine electrical propulsion has been receiving serious attention and for some years has been quietly asserting itself as an art and an industry. The propulsion of ships was one of those greater power applications of electricity which were necessarily delayed pending the perfection of a means of generating large quantities of electrical power cheaply, but the recent advances in design, construction, and operation of the steam turbine and gas and petroleum engines has brought the successful consideration of this problem within sight. At this distance it would appear that electrical transmission of power offers the solution to the ideal slow-speed propeller and a reduction in weight and capacity of the boiler room through the economical operation of the prime mover.

The achievements of electricity in the realm of the newspaper are none the less noteworthy and give every promise of facilitating the movements of this important branch of the industrial field. In the printing shop, the introduction of proper driving motors and controlling devices may be looked for which will revolutionize the art of printing. A striking instance of progress may here be noted. Not long ago the London, England, "Evening News" was enabled to print verbatim a speech delivered by Lord Rosebery in Glasgow, and to have its edition on the streets in London before the speaker had left the hall in Glasgow. This wonderful feat was accomplished through the instrumentality of the electrophone—a specially constructed and extremely sensitive telephone, devised by an Italian scientist.

The growth in demand of electricity for power purposes has led to the adoption of larger generating units and as a consequence, in recent years the trend of manufacturers of electrical machinery has been to show a remarkable progress in the utilization of materials, and in their later machines they have managed to show a larger output in proportion to the quantity of materials used. The demand for larger units has thus been met and it has facilitated the distribution of power over a larger area and at higher pressures. The invention of the suspension type insulator has materially assisted in the design of high potential circuits and shortly we will see placed in operation the 110,000 volt line of the Ontario Hydro-Electric Power Commission, an engineering construction that in magnitude of projection will for some time remain in isolated grandeur.

One cannot but feel that this is the age of electricity and that Canada will have a large share in the gradual uplifting of the industrial efficiency of the world. When the existing power companies and companies of the future have taken full advantage of the magnificent water power resources of this country, the day should not be far distant when a closely woven network of electrical wires will furnish the smallest and the largest centres of this country of ours with all her power requirements for industrial, commercial and agricultural purposes.

The present day electrical engineer must be a broad man. First and foremost, he must be a Booster, a full-fledged member of the Boost Club. His motto shall be: "All together all the time for everything electrical."

The engineer must also be a business man. He must be a firm believer in advertising. Engineers take too readily for granted that the general public are familiar with all the advantages and developments of electrical power. As a rule the public are extremely ignorant in matters pertaining to electricity, with the exception, perhaps, of the electric railway problem.

Above all else the engineer should be an optimist—believe firmly that the demand for electrical power will grow rapidly; encourage a customer to instal a machine larger than his present day requirements; your load-factor may suffer, but do not lay too much stress on this; be big enough to drive through it. Later on, the chances are that this customer will add to his load and thus increase your power-factor. With a small motor connected in, he will over-load and troubles from short-circuiting may frequently be expected.

Lastly, to facilitate electrical progress, engineers must co-operate, not only in the collection of technical data but in the furthering of the general electrical interests. For instance, we should learn a lesson from the experiences of the Ontario Hydro-Electric Power Commission regarding the question of easements for power lines.

We cannot expect to obtain general improvement to the law with regard to easements for overhead lines until a strong case is made out, by the collection of data from all interested countries, showing the present disadvantages suffered. This example is one of many, but will serve to show the urgent necessity for co-operation amongst members of the electrical fraternity.

INDUSTRIAL EDUCATION.

K. A. MACKENZIE, B.A.Sc.

Managing Editor, Applied Science.

That Canada has at length awakened to the advantages and necessity of Technical Education can no longer be doubted. The speech of J. P. Murray, in the February "Applied Science," shows that our manufacturers have been and are giving the matter considerable thought. Technical Education may be roughly said to treat of the application of the principles of science and art to the agricultural, industrial and commercial interests of the country. Before going into the question it might be well to discuss briefly the history of education, keeping always in view that a school education must not only prepare a student for life but also to make a living.

K. A. Mackenzie, B.A.Sc.

The only education in book form which survived the Dark Ages was held by the monks. As years went by, they disseminated what learning they had to their successors and, in homeopathic doses, to the lay population. They appreciated that in book learning lay a power worth preserving. Other learning, the knowledge of crafts and practical knowledge was passed by word of mouth, precept and example from father to son; from master to apprentice; never gathering momentum because there was no literature to preserve and collate its mysteries. Thus it is that some of the practical industrial secrets of the ancients have been lost to the world for long ages.

In those early days began that mutual contempt between the practical, represented by the guilds, and the theoretical, represented by the monks. The latter dominated through the power of logic, from the accumulated philosophy of centuries, over the limited, self-centered and self-sufficient secrecy of the trades. The advantage then gained has made itself long felt and this monk-made education is still dominating our educational systems. It gave us the dead languages, mathematics and philosophy; but it barred from the schools and from the world their practical application.

This was the state of book learning at the time when technical schools were first established. The founders of these schools were in many cases hard-headed men of affairs with large faith in the schools they proposed and small idea of how to accomplish their purpose. These men expected these schools to turn out men skilled in trade; men who should become leaders of men. Since they were to be schools what more natural than that they should engage men from other schools—that is, colleges—to lead them, and what was more natural yet than that these same men should make these technical schools what they are, merely schools with technical leanings. The technical school product thus necessarily failed as practical workmen, but soon evolved into competent designers, engineers and leaders. This was quickly seen and they immediately disdained the very product which they were originally engaged to make. They began to change their schools into engineering schools, which change is at the present day nearly complete.

The graduates of the technical schools aroused the jealousy of the man educated in the shops. The shop trained man had manual dexterity and if he added native ingenuity and mechanical interest he succeeded. The school man had mechanical theory and trained method of reasoning and, if added to this he had a native ability to understand shop processes, he too succeeded; in time, ability being equal, out-distancing his competitor, but those who acquired the necessary dexterity did so only at an expense of time entirely out of proportion to the results gained.

The first attempt to provide skilled workmen having failed, manual training was hailed as the succor needed. Manual training has done all that its real projectors expected but nothing at all of what its later advocates claimed.

Now the trade school movement is having its boom. All over the country there is quite a movement in favor of trades for the younger generation. The barriers between the theoretical and the practical are breaking down. Soiled hands are no longer regarded as not creditable. The pendulum is now swinging the other way, recognizing the usefulness and dignity of the man who makes things. All men cannot be engineers and professional men. From the people, however, comes a demand that there shall be an opportunity for their sons to learn to work with their hands to the best advantage. From the manufacturer comes the demand for educated and resourceful workmen, from the country comes the cry for conservation of all of the raw materials, that of labor included.

The low efficiency of the workmen in various trades in Canada is becoming a cause of concern, not only to the employers and owners of industries but to the leaders of organized labor as well. The present day tendency for specialization has made it well nigh impossible for apprentices to get a good general knowledge of their trades such as in former years was quite possible.

It has been noted, however, that workmen coming to this country from Germany are better all round workers than the average man in the same occupations.

It would be interesting to note the reason of this. In Germany, all children are compelled to attend the ordinary culture schools till they reach the age of fourteen. In these general culture schools they receive also manual training exercises intended for general education. In the "continuation" schools, the instruction is by skilled mechanics and tradesmen. In them one may learn to be a bricklayer, a carpenter, a blacksmith, and so on, receiving a thorough two years' trade school training by experts in the trade.

This system could be easily incorporated into our Canadian educational system. We need similar vocational schools that we may prepare our young workmen to be more efficient workers, more skilful and less wasteful. For years the province has been spending money on general culture and higher technical education with no corresponding outlay for those, and they are the vast majority, who cannot attend school past their fourteenth or sixteenth year.

However, the system could be advanced still further. Hand in hand with our high school system, we need a further, more advanced class of vocational schools for students who have completed their general culture-high school course at the age of eighteen and wish to spend not over two years in becoming proficient in one of the more advanced trades. In these higher vocational schools could be taught occupations such as lithography, printing, machinist, and so on.

This vocational training would not interfere with the manual training which is now given in our high schools and which would be continued as general cultural education, to students in all courses, so that they may have trained eyes and hands, with a knowledge of the arts and crafts in general.

By this arrangement we have provided for the students who cannot go to school beyond the periods of primary and secondary education respectively, by giving them an opportunity in separate schools, to gain vocational training. At the same time we have kept the curricula of the primary and secondary schools free from vocational studies and can devote the time to the work that will best prepare for citizenship and for life in its broadest sense and also at the same time retain a section of our secondary schools for such preparatory studies as are needed for entrance to the university, and engineering colleges. Our engineering colleges should also provide courses more strictly along the lines of industrial management.

The greatest demand made on engineering schools thus far by students, their parents, and their employers, has been for technical specialists, and the need will always exist for graduates prepared to become chief chemists, head electricians, chief draughtsman and designers. But there is also a need for men so trained that they can be developed to fill positions in industrial management. Our industries are at the present suffering from the lack of such men as these—men who are not only thoroughly familiar with productive processes, but have broad human interests and are at the same time thorough business men.

Our captains of industry are recognizing the need of these men, which is a hopeful sign, as it has been proven time and again that any system of technical education is liable to failure unless it is preceded by an active demand from those whom it will benefit.

In the past so large a proportion of our technical graduates have found employment in the large electrical and engineering corporations, that the smaller industries of the country have not availed themselves of the services of technically trained men to any considerable extent. Yet the most wasteful power plants, the most inefficient manufacturing processes, the most uneconomical building arrangements and poorest organization methods are found in the smaller industries.

The young graduate, be he ever so good, and no matter what his course of study has been, will not of course be able to revolutionize matters shortly after his employment in such an industry. Yet he should be able to save his wages many times over, from the beginning, if he has been properly educated.

These men must be trained along three lines. They must be thoroughly grounded in engineering, they must have creative ability in applying good statistical, accounting and system methods to production; and, finally, they must know something about men, possessing some of the innate qualities of leadership, it being presumed it is only the picked men who reach this rung of the educational ladder.

Having mapped out in a slight way the ground of industrial education, the question naturally arises, what parts should the different interests assume in the movement.

The Dominion Government should be the source of information and a centre of dissemination on all questions of technical education to all parts of the country. The United States Department of Labor and the Commissioner of Education perform such an office.

The Dominion Government, which can subsidize a single industry—the steel industry—to the extent of $16,507,200 to develop the raw materials of our iron mines, and its infant industries, should surely be able to subsidize industrial educational to develop the raw material of our labor. A study of conditions in foreign countries shows that the system of vocational schools receives great assistance from municipalities, manufactures and labor organizations. As to the Province contributing liberally there can be no question.

Hon. A. G. MacKay, speaking on technical education before the Ontario Legislature, urged the province to unite with the municipalities in the establishment of craft or trade schools in the cities and towns to supplement the practical training of the workshop, and effect an arrangement as to the basis of their support among the province, the municipalities and the interested manufacturers. He also urged the establishment in large industrial centres of technical high schools, towards the support of which the municipalities should be empowered to contribute.

It was, the Liberal leader forcefully pointed out, no adequate apology for lethargic action on the part of the province to submit that the Dominion was going to "do something." The Dominion, he had no doubt, would do its part, but the Federal Government was careful to observe the limits of its jurisdiction. Education belonged exclusively to the province. The Federal Minister of Labor was sending out a commission for the purpose of gathering information. It was true that efficient and effective industrial education would enhance the trade and commerce of the Dominion, and to this end it was to be expected that cooperation would be extended. But the responsibility and the opportunity were with the province. He urged the Legislature to be up and doing.

In concluding his address he spoke as follows:

"Let us analyze our system of education. We are generous to the high school and collegiate student; we do not withhold our hand to the normal and model school pupil; we are liberal to the university scholar; we extend practical encouragement to those who are in attendance at the Agricultural College. All this is well. But what about the lad whom chill penury sends to the workshop at an early age? We don't spend a dollar on him.

"Let us be frank and honest with ourselves. Our educational system is poorly balanced. It is a matter of vital importance that this should be remedied. It touches not alone the industrial problem; in the larger sense it affects the ethical side. The State cannot afford to drop these boys. The need of the day is something for the child of the wage-working class.

"This is not a political matter. It is provincial. Neither the old Government nor the present Government have evolved any adequate solution of the problem which confronts us. We mean well enough, but we lack intelligent direction. It is high time to do something."

By all means one of the most important functions for the Dominion Government to take up is the question of **Research**. This could be done by the establishment of a National Research Bureau similar to the Watertown Arsenal, the Structural Material Laboratory at Pittsburg, Pa., and in connection with the different laboratories of the leading American Engineering colleges.

The executive of the Canadian Society of Civil Engineers are now pressing the Federal Government along these lines.

Tuition would be in no part the duty of the Research Bureau. It should be manned by the best men obtainable. Their work would consist in the investigation of our resources, whether occurring directly in nature or as by products in our industries. There are a thousand and one problems awaiting solution. The problem of electric treatment of iron ores, so ably handled by Dr. Haanel, is an example. Many sources of economic waste might easily be stopped and millions of dollars added to the national wealth. On this phase the example of Germany need only again be quoted to show its importance. The difference between success and failure, between partial success and wealth, often lies in the waste heap and the treatment of by-products.

Too much attention cannot be given to the research problem in our universities. In our Canadian engineering colleges we are sadly hampered by the lack of funds and equipment. The possibilities for good by direct results and the training of men capable to carry on further investigation are obvious. In Ontario to-day the problem of sewage disposal is ever pushing itself more into prominence, yet we have little or no definite knowledge as to local problems. It is true that the Ontario Government has established a laboratory in Toronto, but this is being treated more as a bacteriological station than for investigating the problems of sanitary engineering.

The example of the Sanitary Research Laboratory and Sewage Experimental Station of the Massachusetts Institute of Technology at Boston need only be quoted to show the possibilities and the immense advantages to be derived from such a station. In other lines, the work that the Agricultural College at Guelph does for the agricultural industry might be duplicated for the manufacturing industries.

The Faculty of Engineering is the only Faculty of the University of Toronto lacking research scholarships. This hinders the work greatly. The graduates are taking the matter up and promise soon to have a start made.

A movement should be started to keep before the manufacturers the possibilities of research. This might possibly result in a manufacturer or a group of manufacturers providing funds for the maintenance of a fellow whose time would be primarily employed with a particular line of research, but given in part to university work. This plan has worked successfully in the University of Kansas, being introduced by one of our Toronto graduates, Prof. R. Duncan. Its initiation here would give an immense and needed impetus to the work in the University of Toronto.

THE TECHNICAL WHO'S WHO.

PREFACE.

"Applied Science" does not hold itself editorially responsible for the opinions expressed in its papers by authors.

A canvasser has requested Mr. E. C. Easy, C.E.—that walking stress diagram of eminent engineering intellectuality—to join the new social club for technically trained men in Toronto, and desired to know whether the notable expert wished to be fyled away as an engineer, or a surveyor, or an architect; and if the first, what kind of one. There was the rub. Mr. Easy could not make the grade.

The great man was undeniably cross. He unloaded himself on poor, defenceless me. He does not usually employ strong language but he flung everything to the winds on this occasion. He smote his thigh.

"Crumbs!" said he, "Bread crumbs!" With that he blushed.

"Whither are we drifting?" querulously he demanded, his thought-corrugated visage astare at the ribs in the arched ceiling. "Where is our ancient and honorable profession off-getting-on-at? What would Stevenson have thought, what Smeaton said, not to mention James Watt and other foot-rule gentry—the old masters of rare technique who inveigled their pictures into history, as authorized for use in the public schools in Ontario." Mr. Easy shifted his chair and contrived a bow-knot out of his long legs. He was getting wound up.

"I would just like to have glimpsed the dago face of him had *Nonius Datus,* Esq., C.E. (A.D. 152),* the underpaid hydraulic engineer of the Third Legion, been button-holed, as to his *toga virilis,* by my friend the canvasser.

"He said he was a young engineer. He had a viz that looked as if a lot of field rivets had been skipped. But he was oily—slicker than the hair on a Petrolia frog. He was so smooth he wouldn't retain at 50 to 1, and that's agoing some, as they say in the Arithmetic. However, he didn't get mine in his bunch of classy tracing-cloth signatures. This new club is to consist of engineers, architects and surveyors. Do you take me? A dinky triangle of money-needing forces. Now, as proved by laboratory tests, I'd crave to enquire, where's the dividing line, the party wall. When they say engineer, do they mean engineer, or (perhaps it is shown plainer on a section), when is a hen?"

I kept still, perfectly quiet. Mr. Easy—that past master of scientific profundity—was not one to be argued with. Perfect, beatific stillness. The sound like a giraffe gargling was only a water pipe outside.

Mr. Easy resumed. "I s'pose that fat-head canvasser tried to see would I get rattled; must think I'm chief engineer at a mechanical toy factory—baby rattles a specialty. He is apt to be in the Burke's Peerage of Smart Alecks who would belay you to a street corner and cause you to miss a transfer while he contributed to your already over-flowing think-reservoir the balmy, uplifting hypothesis that hydraulic engineers trek in two brigades—those who work at it and those who drink it. The muzzle legislation should include the likes of him. Wouldn't his pronouncements add to the gayety of nations and merit a floral tribute of price; wouldn't the mover stand a good chance for the chairmanship—he'd be carried out unanimously. Never mind, don't worry, the golden orb will yet rise on a working day of 24 hours when he'll find his own level — also transit. Civil Engineers and impolite surveyors alike are often fain to. And often borrow them—also other articles of a field-work toilet."

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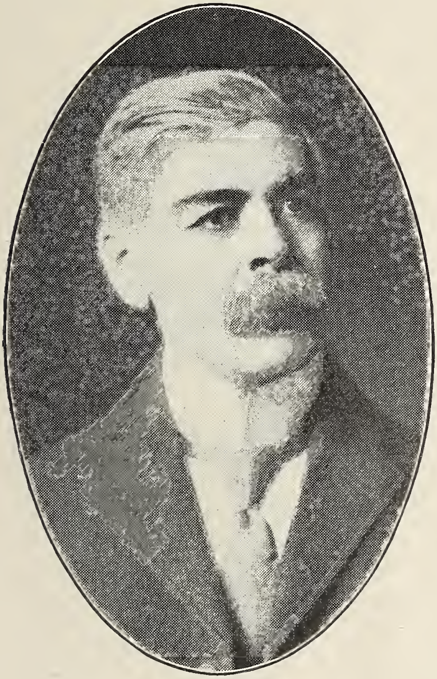
* Dean Galbraith's Valedictory as President of the Canadian Society of Civil Engineers (1909) was evidently surging through a certain brain, which we will designate as "X"



C. M. Canniff, B.A.Sc.
(E. C. Easy, C.E.)

"Bug-house! I should so conjecture. Right up to the nth! He'll never turn out any John G. Pocketfiller, or J. Bluepoint Sturgeon, or Lord Skincoona. That's my one best comment. I fully expected him to volunteer that a sanitary engineer is one who may be crazy, but lacks the funds to board at a decent, comfortable Insane Asylum. Oh. Crumbs! Also that a Railway Engineer, if you get on to his curves, is different to all others, because he travels in a special train of thought. How would that hit the genial, sage, and strictly moral architect of a jerk-water stump-dodger? Without the aid of a lens one could discern the palpitating bulges made by pathetic, lost-chord, looney ideas of that character taking exercise in his forehead's back-yard."

"I expected him to tell me that Mining engineers are noted for doing a lot of low-down work, and being experts on the seamy side of life. What? No, that canvasser's got no surcharge of technical fill behind his back. He an engineer!

Crumbs! Crumbs! If he were my assistant for about a minute I'd kink his tape, I'd glue up his slide-rule."

"He'd not be suggesting any more that Roadway engineers should mend their ways; or that a Surveyor's best plan is to make both ends meet when he starts in to callous his elbows over the drawing-board; how would they, for instance, like to be told that surveyors don't work at all—simply are low comedians, playing problem plays at measure for measureable wages? Like as not one of his simpering inanities would be that all engineers, save the stationary fellows, are generally working themselves out of a job. I believe really that that chap could encase a square meal and dreamlessly go to 'bye-bye' after defining a civil engineer as one who made mountains out of mole-hills, and vice versa, each to each; likewise explaining how they were called civil, enjoying as they did a bowing acquaintance with other clans of engineering talent."

"Answer me. Why can a punk applied mechanic like that buy India ink at the same price I pay? Consider not a kid-gloved vernier twister at all—for even a common draughtsman who draws the line at $40 per—making black scratches on white paper—could tear off reams of lunatic specifications like that. Possibly have the decency to accord his face a flat-wash of carmine too. A licensed set square chauffeur doesn't amble forth in the stilly night and imagine himself formed into a scientific brain merger every time he feels chesty enough to buy celery and Roquefort after an evening's close figuring at the Star Theatre or the Gayety. He resembles our University—he's got some reasoning faculties."

"How would a surveyor like to be called a *'Poduk-asin Ashish-kie-ikank'* just because it's Ojibway for 'stick-in-the-mud.' That's the brand of insipid sop his crater would be liable to erupt. He'd be spending that grade of small change like a soused inmate of one of our saucy Canadian Dreadnoughts. It's enough to make a really truly and sincerely engineer hire an aerotaxi and drome away and dee."

There are engineers by profession and those who profess to be engineers. Both amateurs and professionals enter the engineering Marathon. As Peary remarked with that 'welcome-to-our-Polar-City-smile' of his: 'Many are Cooked but a few are frozen.' More probably Peary was considering a human being than cold storage meat. What yer know 'bout dat?"

Now, it is an interesting—to most a likeable—attribute of Mr. Easy, this eminent authority with a strangle-holt on technical wisdom—that one can rarely fathom whither his next thought is trending. In his public or private life one can say, like the girl with steel corsets who learned to run a compass—he has a certain inherent attraction in his surroundings.

"I'll bet a silver-plated protractor as big as a cart wheel," asserted he, "against a rusty pair of spavined dividers that that pin-head canvasser will suggest to the Chemical engineers a letter-heading along the line of the attached sublime sentiment:

'Little Johnnie's dead and gone,
'We'll never see him more;
'For what he took for H_2O
'Was H_2 SO_4.'

Dot is sense, vot it is, is it? Ach!

"How would an individual who ponders week in, week out, in terms of galls. per sec., or lbs. per sq. in., care to be told that a Mechanical engineer can be identified by the oil he puts in his salad dressing? Would getting caught in a belt like that be a relish? Oh, you kiddo! Would you subscribe to a Structural engineers' being one who approves a rotary mixer rather than every-day Radnor, or an occasional observation of Apollinaris, with its accustomed satellite. Details of the personal character of Electrical engineers, with him, would pass current for juicy. Isn't that joke ripe for its old age pension? Do Elevator engineers make a social pastime—a pay-as-you-enter relaxation—out of the gold cure? Woe's me! I imagine he considers the Architect's function is to take an engineer's plan and dot the i's and cross the t's, and put some curlimagigs on the capitals."

It was at the Engineers' Club that Mr. Easy had unbosomed himself to me as above. Two or three members had joined us in the interval. Then the power went off, the lights went out, and everybody made for the street. As I felt my way down stairs I could catch some drift of a hit-the-bull's-eye definition of an engineer: " a man" (as near as I could gather) "with a quality of brain to figure out beforehand that it's not necessary to turn a horse upside down to get on its collar."

Here a slip on a step, and a quick-fuse, muttered invocation to—sounded like "Happy Hooligan" or "Holy Hexigons." Then a match scratching....a little later, "but that canvasser.... light another match, light two, light a box....his advertisement would read....

"'Bridges Designed Free.
If not Built
No Harm Done.'"

And next...."Sure! He was *maison du scratch*....them's Penetang French for 'bug-house.'"....Another slip on the stair.... a determined, seismographic, a most tasty one, likewise a flash down below like Halley's comet, then a convulsive "Thank God! Cheer up, here's the door. O, Crumbs!...." When I reached the street Mr. Easy and companions had faded and gone. All was quiet. I found my way and wended it. The new club is determined upon getting the most eminent engineering prodigy of our land and age to join, but it is still on the waiting list.

WHAT THE GRADUATES ARE DOING

This section is conducted with a double object in view—First, to give the graduates professional news of each other; secondly, to give the undergraduates an idea of the possible fields of employment open to them in the future.

Walter Jackson, '07, is with the Ontario Power Co. on the construction of their second conduit.

N. C. A. Lloyd is employed on construction on the Canadian Northern Ontario Railroad on the Ottawa-Toronto line.

R. Pettingill, '06, has been transferred to the Port Colborne plant of the Canadian Cement Co., being in charge of the chemical department.

Frank G. Mace, '05, is employed in the Patent Office, Department of Agriculture, Ottawa, as Patent Examiner.

T. Harry Mace, '05, consulting engineer, Confederation Life Building, Toronto, is taking over the engineering office and business of Baker & Jordahl after being their chief engineer for a year and a half. His specialty is power lay-outs and transmission and reinforced concrete design.

J. F. S. Madden is with the Canadian General Electric Co. at Winnipeg.

K. G. Marlatt is at present in London, taking a post-graduate course at the Leather Sellers' Company Technical College.

C. H. Marrs, '02, is designing engineer for the Riter-Conley Mfg. Co., at Pittsburg, Pa.

D. W. Marrs, '06, is also with the Riter-Conley Mfg. Co.

W. A. Maxwell, '06, is with the Canadian Bridge Co., Walkerville, Ont.

D. D. McAlpine, '09, is with the General Electric Co. at Pittsfield, Mass.

A. S. McCordick is with the City Electrical Department, Toronto.

F. H. McKechnie is employed on construction with the National Transcontinental Railway, Cochrane, Ont.

H. L. McKinnon, '95, is chief engineer of the C. O. Bartlett & Snow Co., Cleveland, Ohio.

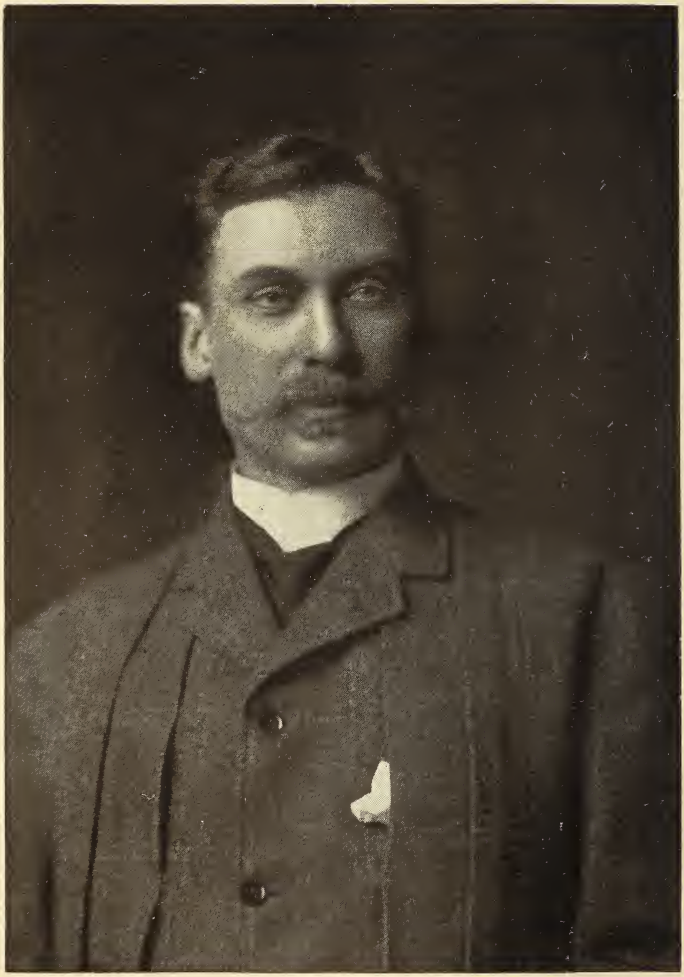
K. McQuarrie, '07, is assistant engineer on Maintenance of Way, Vancouver Division of the C. P. R.

H. G. McVean is at Moose Jaw, Sask.

L. H. Miller, '00, is chief sales agent of Bethlehem Steel Co. for Ohio and Michigan.

E. D. Monk, '08, is assistant chief of Testing Department, General Electric Co., at Pittsfield, Mass.

J. E. A. Moore, '91, is a consulting and contracting engineer at Cleveland, Ohio, specializing on the design and superintendence of manufacturing and power plants.



R. W. Leonard.

Applied Science

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THE SCOPE OF ENGINEERING IN CANADA.

R. W. LEONARD, C.E.

Mr. Chairman and Gentlemen,—I esteem it an honor to have been requested by the President of your Engineering Society to address you on some engineering subject of my own selection, and in a rash moment I consented, not realizing at the time that your Society embraced men of wide experience in the many fields of engineering since graduating from one of the foremost technical schools in America.

Since realizing the gravity of the situation and balancing it up with my natural aversion for hard work, I have decided to give a very general short address on engineering in which the points dealt with may be very stale and uninteresting to the seniors, but may be of some value to the younger members who are the only ones I can hope to influence, as I am not long out of the ranks of juniors myself, having had very little experience in some essential matters—particularly, as you will observe, in making addresses in public.

In this connection I may express my admiration of the teaching of the art of public speaking which is now given generally in some of our colleges. In my day at college, this was neglected and the result is that I have several times envied the assurance and ability displayed by youngsters of fourteen years in public speaking. This is an important matter for an educated man in any walk of life that he may be able in public to express his thoughts logically, clearly, and concisely, and with the confidence that comes of practice.

An engineer, according to the dictionary, is one who uses or has to do with the construction of engines or machines; or of works in which machinery is extensively employed. He is also sometimes defined as one who utilizes the forces of nature for the benefit of man. Someone whose energies were mostly directed toward railway location, construction and maintenance, has defined an engineer as "a man who can make a dollar do the most work." This last is a definition not to be despised as the financial result is one of the most important measures of the

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* Read before the Engineering Society, Oct. 5th, 1910.

success of all engineering problems, and any man who cannot carry out his work satisfactorily in this regard will not be considered by his employer as a successful engineer. On the other hand, where a reasonable expenditure will place the success of a work beyond peradventure, the expense must not be spared.

Advancing civilization has so complicated man's requirements and multiplied the field of endeavor of the man whose profession of old was confined in the army to the handling of artillery, and in civil life to the construction of roads, bridges, buildings, and steam engines, that perhaps a good definition today of an engineer would be "a man who does things."

By the way, the Ancient Romans designated the chief of the highest members of their great colleges of priests, Pontifex Maximus, or the Chief Bridge Builder, from which we get the word Pontiff, all of which shows the early connection between the church and the civil engineer, and is only another proof of its antiquity, respectability, and honor of the profession, and explains the affinity of engineers to the church which is so conspicuous to this day.

All this raises the question if the French name "Ingineur," spelt with an I, and probably related to our word "Ingenuity," would not be a more appropriate designation for our profession. This is a suggestion which I leave to some of you who know something of philology.

Reverting to the financial definition of the term engineer, and assuming its correctness in many branches of the profession, then, an engineer's education is not complete until the engineer has had experience in executing the work as well as in the planning of it, and the measurement of it as done. In my opinion therefore, a young civil engineer who intends to specialize in public works, such as railway, canal, or dock work, should take one contract for the purpose of learning the "practical" part of the work—what the dollar is worth in labor and material, and how to use it to best advantage. He may lose money, but he will gain more valuable experience. My first appreciation of this practical knowledge was acquired through observing a successful contractor timing with his watch the trips the teams were making with the wheel scrapers, and figuring the cost of moving the earth per cubic yard therefrom.

Now, as my remarks apply to the juniors of the profession, I will venture upon some advice based on my limited experience, notwithstanding my familiarity with the saying that "advice is worthless, as the wise man does not need it, and the fool won't take it." One of the first things necessary to success in life is a full appreciation of the value of "law, order, duty and restraint, obedience, discipline," as Kipling puts it, in other words, executive ability. These are not taught or practised in all colleges, and more's the pity for the chances of success in after-life for the students. These can best be acquired through military training which is well worth your while, for these reasons alone. What a common experience it is to find a well-educated technical man absolutely unqualified to direct the operations of half a dozen men! Cultivate a spirit of absolute loyalty to your superiors, speaking of them and to them respectfully on all occasions with deference to their opinions. Require the same deference from your subordinates while on duty and this is best taught by your own example. Be equally loyal to your subordinates, paying attention to their suggestions and recommendations, and giving them due credit when you find their advice worthy of adoption. This brings out their hearty co-operation and insures their interest in the work. The advantage of such co-operation is apparent if one thinks of how little he alone can do and how much he is dependent upon the detail work of his assistants.

When given an opportunity to reorganize and carry on a work started by another, don't make radical changes too quickly. Better continue in the old methods for a little while, even if apparently faulty, until you have ample time to fully grasp the situation, and then make changes one at a time, using the men and materials on the work so far as possible.

Learn to judge men and their ability from personal observation rather than from written references, and if an assistant is not a success in the work you have set him to, try him in some other department, if he be a desirable character. By so doing you will get a staff about you whose capacities are known and on whom you can rely. This is on the old principle that " 'Tis better to live with the devils you know than to go to the devils you don't know."

Of course, no one man can get a thorough education in college in all the branches of the profession, including mechanics, mining, metallurgy, chemistry, electricity, hydraulics and sanitary engineering—as it would take a life-time.

There is a general ground work common to all, however, that can be acquired at college, and the actual education in any one branch must be obtained by the student after leaving college through experience and close study. This remark is intended to chasten any youngster who has just got his degree and who might therefore consider himself fully qualified to teach his maternal ancestor the noble art of sucking eggs. Please do not infer from this that all the older members of the profession are "grannies," as I am too nearly graduating into their ranks to make such a suggestion.

Though that tendency of some graduates is not to be commended, engineers need to have much self-confidence, and be prepared in this young country to take hold of any work in any branch of the profession that may present itself, and must have the courage to take the responsibility of that work and to carry it through to success.

A few years ago in Canada, civil engineering meant railway or canal surveys and construction, and some water supply and sewage works, and the profession consisted of a very small but select company of men, who set the pattern of loyalty to employers, of industry and integrity to the latter generation that the civil engineers in Canada to-day are proud to acknowledge and to emulate.

I remember being one of only three candidates for matriculation in the faculty of Applied Science at McGill, and I dropped out for want of necessary funds to take the course. Now the students in Applied Science in Canadian colleges are numbered by the hundreds and the Can. Soc. C.E. enrolls about 1,400 corporate members, and one of our ablest engineers estimates that "it requires the expenditure of $150,000,000.00 per annum on engineering works to keep us all employed and give us a moderate remuneration." . . . . . "And we cannot expect the long continuance of the expenditure of capital for engineering works which is required to keep us all going."

If the saying attributed to one of our foremost statesmen that "The 20th century belongs to Canada," and I believe it does in the sense of a vast increase in population, wealth and importance, then surely this increase is to be effected through the agency of "the men who do things" or the engineers, and in my mind, there can be no overproduction of engineers provided they be well equipped by a proper training along the broad lines of engineering suggested.

We must bear in mind that the opening up and developing of a new country with its consequent requirements in public works and industries of all sorts is not effected by the lawyers and the physicians (important as these professions may be), and we must see to it that our educational institutions are kept alive to the requirements of modern civilization, the necessary education for which is no longer crystallized in ancient books written in the dead languages.

To my mind this means that many of you must be prepared to take up mining, metallurgical, electro-chemical, and other industries which are best managed by the educated engineer, and that there is ample work for an immense number of men educated along the lines indicated in Canada. Consider our advance in mining alone. The mineral production of Canada in 1886 was $10,221,255; 1896, $22,474,256; 1906, $79,057,308; 1909, $90,415,763, or $12 per capita, as against $2.23 per capita in 1886—and we have just begun.

Northern Ontario and Quebec have scarcely been glanced at as yet by the prospectors, yet you are all familiar with the fact that Ontario produces the bulk of the world's nickel and about 12 per cent. of the world's silver and much of its corundum and mica. Quebec produces most of the world's asbestos.

Our prairies and British Columbia contain the coal that is essential for the existence of the population flowing in there, and for the North Western United States.

We have many hundreds of miles of the same rocky mountains that have produced all the fabulous wealth in silver, gold and copper, in South America, Mexico, and the Western United States. In Canada the development of these undoubted mineral resources is comparatively slow, owing to climatic conditions in winter and the general distribution of forest growth owing to the moister climate—meaning so much greater things for the ultimate welfare of the country.

Here we see forest growth and forestry entering into the domain of engineering and raising the question of how nearly allied is the science of forestry and the conservation of other natural resources to our profession. Here are a few figures to measure the question by: In 1887 I built a large coal-loading wharf in Nova Scotia, the hemlock timber for which cost $4.50 per 1,000 feet B.M., sawn in bridge sizes and loaded on cars. It had been cut down for the tan bark, a part of what would otherwise have rotted in the woods was utilized for the wharf. The present price of such timber there would probably be $20 per 1,000. About 1891, in Parry Sound District, white pine hewn to railway bridge sizes was delivered at the site of the structures for $7.50 per 1,000 feet B.M. During the past two years nearly all the timber of the same sizes required for the mining buildings in Cobalt has been brought from British Columbia at a cost of about $27 per 1,000.

The "inexhaustable" pine forests of Canada are of the past as our other forests will shortly be if we do not take extraordinary precautions towards conserving and replanting them. A recent fishing trip in the northern portion of Quebec impressed me with the importance of the work being done in this respect by our professional ancestors, the beavers. They have been protected there for some years, and have increased until they are very numerous and have flooded every old-time dry beaver meadow and raised the level of every pond and small lake from two to four feet. In the aggregate this must have an important effect in checking forest fires and conserving and regulating the flow of water in the rivers, and benefiting the conditions desirable for the operation of water powers.

Coincident with the increased cost of timber we find a decrease in the cost of Portland cement of much superior quality which is rapidly taking the place of timber in many structures.

When reinforced with steel we get a most important new building material, the proper use of which is an art almost worthy of forming a separate branch of Civil Engineering.

Concrete is beginning to be used in ship-building. Barges of reinforced concrete are said to be in use in Europe, and it is said that one is being designed to be built in Ontario. It would appear that the design must be very simple, or the cost for timber forms will be excessive. The economical use of lumber for forms for concrete structures and the design of structures to this end, forms a subject well worth much more attention than has generally been given it to date.

To return to this very important subject of transportation, which a few years ago engaged almost solely the engineering skill in Canada.

Beginning about a century ago, the rapids of the St. Lawrence were canalized for small boats, and a similar canal was built at the Sault by the Hudson Bay Company. Then followed continuous enlargements, the construction of the Welland Canal begun early last century by private enterprise and afterwards enlarged by the Dominion Government, until Canada has transportation facilities for ships of over 2,000 tons carrying capacity through the greatest canal system in the world right from the Atlantic to the head of Lake Superior equally free to ships of all nations.

During the past few years the Dominion Government has had surveys made of the proposed Ottawa ship canal to take ocean ships from Montreal up the Ottawa and Mattawa Rivers to North Bay, and down the French River to Lake Huron, at an estimated cost of over $100,000,000. It would appear to me that this should be the next large national public work to be undertaken so soon as the country has the National Transcontinental Railway completed and satisfactorily financed. Its construction will be warranted as a transportation route, to say nothing of the value of the water powers to be developed thereby, and its value for defence purposes. As a comparison, consider the cost to the State of New York of $150,000,000 for the enlargement of the Erie Canal to carry barges of 1,000 tons only from Buffalo to Troy.

Our western country is greater and of more value, I believe, than that of the United States.

In railway work the Grand Trunk was the pioneer and served the southerly portions of Ontario and Quebec exclusively for many years. Then followed the Intercolonial, forming a bond of union with the Maritime Provinces, thus making possible the consolidation of the Easterly Provinces within one Dominion.

One of the terms of the Confederation of British Columbia with the Dominion was the early construction of the Canadian Pacific Railway, which had been started as a government measure in the seventies. The Canadian Pacific Railway represented by a syndicate of leading Canadians, undertook the work early in the eighties, and in a remarkably short space of time, completed the laying of the rails to the Pacific in 1885, at a time when many of the people of this country declared it would never earn enough money to pay for grease for the axles. I was on the construction of that road north of Lake Superior when the "syndicate" had exhausted its means, and for about six months we, the engineers, got no pay. Now the earnings of this, the greatest railway system in the world under one management, is close to $2,000,000 per week.

Now the National Transcontinental Railway is being constructed, duplicating our railway transportation facilities from Moncton, N.B., to the Pacific, at a distance to the north of the Grand Trunk and Canadian Pacific through Ontario and Quebec that is giving that part of Canada a width from north to south undreamed of a few years ago.

The Canadian Northern Railway is another road which in a few years will be a third transcontinental highway for Canada, the country that 25 years ago was estimated by many of our people as being unable to pay for grease for the wheels of one. At that time many of our people were leaning strongly towards "commercial union" or "annexation" with the United States as our only salvation from financial ruin.

I have been reading "The Valour of Ignorance," by Major-General Homer Lee of the U. S. Army until I am almost a believer in annexation myself, the annexation of the United States to Canada. Read the book, it will repay you.

This Canadian Northern Railway is being built by two Canadians who started in life without any special educational or other advantages than industry, any amount of pluck and an abiding faith in the future of this country. Now they are probably the greatest railway owners in the world, and bid fair in a few years to own as a partnership of two a complete transcontinental railway of several thousands of miles, to say nothing of their other enormous interests, street railway, mines, steamships, and other engineering works.

In water power development Canada ranks almost first with nearly a half-million horse-power developed or being developed in the Niagara District alone. Consider the value of this to the territory served by this power by comparing its cost at, say, an average of $25 per horse-power per year for 24-hour service to the consumer as against the cheapest other available power, the gas engine at, say, $50 per year, or the steam engine at any price from $75 per year to $150 per horse-power per year.

In 1893 I had charge of the construction of a very large (at that time) hydro-electric plant at Niagara Falls, Ontario, for the Park & River Railway Company. We developed 2,000 horse-power and the best electrical authorities advised that it was cheaper to put in and operate a steam engine and generator at Queenston to operate cars on that grade, 12 miles from the power-house at the Falls, than to convey the current from the main power-house. It was put in and operated for some years. Now we see that same power being carried a couple of hundred miles at 110,000 volts. Have we reached the limit?

Well, the subject of engineering is so wide and Canada is so big and so full of opportunities for any one who is industrious that were I gifted as a speaker I could continue along this strain till you are all asleep.

However, I will close with another word of warning:

We are rapidly acquiring much desirable national wealth and are no longer a small number of poor people struggling for a bare existence along a northerly fringe of the United States, as we were a few years ago.

As our national wealth increases and our importance is recognized by other nations, we become more subject to the envy of those countries in Europe, Asia, or America, whose populations are sufficiently dense to desire room for expansion, and we must therefore be prepared to defend our property unless we are content to become a conquered people subject to laws and customs which are alien.

This may seem to many of you as far-fetched or exaggerated .Again, I advise you read "The Valour of Ignorance," by Homer Lee.

Let me call your attention to the words of Mr. L. S. Amery, Colonial Editor of the London Times in an address at the Canadian Military Institute the other day.

"We do not," he said, "consider the work of the sanitary engineer or the physician in defending the community or the individual against disease as unproductive or unnecessary, or the work of the teacher in defending the child against ignorance, or that of the clergyman in defending his people against immorality, or of the lawyer in defending his client against imposition and injustice, as unproductive and unnecessary work. Neither should we consider the work of the nation in providing munitions of war or the work of the soldier in preparing himself by study and training to defend his home and country as unproductive work. All these are essential to national existence and to national development."

He believes that it was the duty of every able-bodied citizen to prepare himself to defend his country. "A nation that looks after the physical, intellectual and moral development of its people by means of the necessary military training will solve all of its other problems. Its industrial and commercial efficiency will be enhanced because of the patriotism and capabilities of its trained manhood. Perhaps a few people say that Canada has no need for a defence force, that Great Britain will defend this country, or this nation can lean on the United States; surely Canada does not desire to be a parasitic nation. She does not, and will not, wish to lean on anyone."

Some men who have not studied the subject have declared that Canada need not bother about means of defence, as the United States with her "Munroe Doctrine" will protect us.

As Homer Lee points out, "In the time of Munroe, it was impossible to foresee the changes mechanical inventions were to make in the political development of the world after his time.

No longer, as in Munroe's time, does a vast Atlantic separate this continent from Europe. Man's ingenuity has reduced it to a small stream, across which the fleets of European powers can cross in less time than it took Munroe to post from Washington to Boston."

He speaks in the same strain of the Pacific Ocean, and points out the imminent danger of a Japanese conquest of the Western United States, owing to the absolute commercialism of our neighbors to the south, and their neglect to take the necessary precautions of defence.

Assuming that some military and naval force be necessary to the existence and welfare of this country, we live in a too democratic age to permit a small number of our men who are sufficiently patriotic to spend their time, means, and possibly their life's blood to defend the others who sit at home in ease and—for a small price paid in taxes—enjoy the privilege of reading these things in the daily papers.

I do not wonder at the agitation for woman suffrage. Have they not as much right to vote as their brothers who refuse to take a man's part in being trained for the defence of their firesides?

Apart from all military considerations, every engineer who may have to do with organization of forces of men, or of a staff to direct any operations in the engineering profession, will find that the discipline which can be learned only in military life gives a very important advantage over his competitor who has neglected his opportunities along this line.

I know many will say "There is no time. All the time we can spare from study is taken up in music, or football, or cricket, or the gymnasium." These are all good, but to my mind, they do not compare with the military training which is as important as mathematics.

I am pleased to know that the University has one military organization, a field company of Engineers, which trains about one hundred men.

We should have every man in the University who is physically fit enrolled and given the opportunity of learning to obey before he is called upon to command and of obtaining the first principles of a training that will fit him to help to defend when necessary this Canada of ours, and to keep it for all time a part of the greatest empire the world has seen.

You may find, as do most engineers who stick to the purely professional side of the work, that the prizes in the profession are few and not very large when compared with responsibilities and the labor; but when all is balanced up, you will be able to say you have lived a man's life among men, and have done something that has left its mark on the development of your country, and have been of service to your fellowmen.

NOTES ON THE ELECTRO-METALLURGY OF IRON AND STEEL.

T. R. LOUDON, B.A. Sc.. A. M. Can. Soc. C. E.

Although the electric furnace has been used in the metallurgical industry for a considerable period of time, it is only within recent years that it has been possible to successfully produce pig iron and steel on a commercial scale. At the present day, the problem of mere mechanical operation seems to have been solved, so that it is only a question of efficiency and cost of electric energy as compared to ordinary fuels that determines the commercial value of the electro-thermic process for any given locality.

It will be the endeavor in this article to explain concisely the working of a few of the different furnaces used in the electro-thermic reduction of iron ore and the subsequent production of steel. It is, of course, understood that the accompanying drawings are extremely diagramatic. They will, however, serve very well the purpose of illustrating the theory embodied in each process. Should the reader care to go more fully into the question, there will be found throughout this article reference numbers, the key to which is given at the end.

Before discussing the various processes, it is extremely important to understand the part that electrical energy plays in the production of either pig iron or steel. In the ordinary process of smelting, the ore, together with limestone and coke, is dumped into the blast furnace, and as the result of certain chemical reactions that take place, pig iron is produced. Stated in as simple a manner as possible, the hot coke at the lower levels in the furnace meets a blast of air, and the ultimate result is that there is a formation of carbon monoxide gas. This gas, together with the carbon of the coke, reduces the iron from the ore. Now it is a matter of common knowledge that it would be impossible to bring about this reduction of the iron if the process were not carried on at a high temperature, and in order to attain this temperature, a certain percentage of the coke in a blast furnace is there for the purpose of producing heat. So then it is seen that the coke is present for two definite purposes: (1) To provide an agent with which to reduce the iron from its ore (2) as a source of heat. It is for this last purpose that electric energy is used; i.e., as a source of heat.

Working on the basis that the requisite heat is to be supplied by electrical means, if the cost of electrical energy required to give the same amount of heat as a ton of coke be figured out, it will be found that the price of coal for coking would have to be extremely high, and electric power very low before one could ever hope to replace the former with the latter. This calculation, however, takes no account of the fact that electric furnaces are far more efficient in their utilization of heat than furnaces using ordinary fuels. When these efficiencies are taken into consideration, it is found, roughly speaking, that with electrical power costing ten dollars per electrical horsepower per year, and coal at about eight dollars per ton, the electric reduction furnace may compete successfully with the ordinary blast furnace. These figures are, of course, the extremes in cost, but there are many localities where such conditions exist. (Reference No. 1 and 2).

As in the making of pig iron, so with the processes for making steel; the electric current is the means of providing heat. The ordinary furnaces for making steel, however, are far less efficient in their utilization of heat than the blast furnace. so that the electric steel furnace with its high efficiency is able to compete with some of the other processes under the ordinary commercial conditions. This is especially true where the electrothermic process is used in conjunction with the ordinary processes.

Electro-Thermic Reduction of Iron Ore.

Roughly speaking, the reduction furnaces in use at the present time may be divided into two classes; those with vertical electrodes embedded in the charge; and those with the electrodes projecting into a crucible at the lower part of the furnace. Both of these types are known as "resistance furnaces," due to the fact that the heat is generated by the resistance offered to the passage of the current through the charge.

The simplest form of furnace is that shown in Fig.1. The carbon electrode A is suspended by some regulating device in the charge of ore, coke and limestone. The crucible walls and the hearth are made of a carbon paste, in which is embedded a second electrical connection, C. If, now, the circuit be closed, the current in passing from A to B, or vice versa, will, owing to

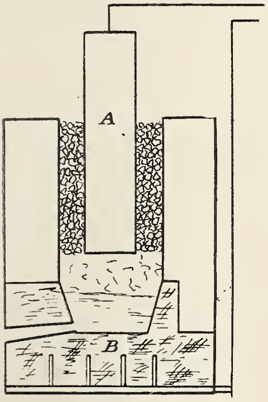


Fig. 1

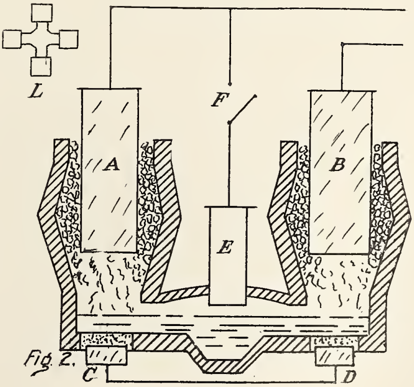


Fig. 2.

the high resistance of the intervening charge, develop the necessary heat requisite to attain the desired temperature..

A furnace of this type was successfully used in the experiments carried on at Sault Ste. Marie by the Canadian government under the direction of Dr. Haanel. While these experiments were entirely satisfactory, it was pointed out on their completion that there would have to be some modifications made in order to allow the charge to feed regularly and to utilize the gases as they escape from the top of the furnace. An attempt was made at the time to make use of these gases by introducing an air jet into the charge near the top, thus burning the gases, but it was found that the charge became sticky, and was inclined to "hang"—a very bad fault. (Reference No. 3).

Fig. 2 represents a type known as the Keller furnace, invented by Mr. C. A. Keller of France. A and B are two carbon electrodes. Embedded in some conducting material in the hearth are two electrodes, C and D, connected together as shown. To begin operations, A and B are lowered and the charge packed around them. At first, the path of the current will be from A down the charge, across from C to D and up the charge to B, or vice versa. As soon as the iron covers the hearth, however, the current instead of passing around the shunt from C to D, as described, will take a path through the molten metal, thus tending to keep it warm. Sometimes, though, the bath may cool at the centre. If this occurs, the auxiliary electrode E is brought into play by closing F, part of the current then passing through the central portion of the bath, giving a greater intensity in that locality.

This furnace may be built with a plurality of hearths, as indicated at L, Fig. 2, each of the small squares representing a stack with its vertical electrode. By this arrangement the electrodes may be arranged in pairs in parallel if so wished, thereby giving a better system for regulation. (References Nos. 4 and 5.)

Leaving for the time being the discussion of these vertical electrode types, there are shown in Figs. 3 and 4 two furnaces of the second class indicated previously.

Fig. 3 shows diagramatically the construction of a furnace which is the outcome of a number of experiments carried on at Domnorfvet, Sweden, by Messrs. Grönwall, Lindblad and Stalhane. A number of different furnace shapes were tried until finally the construction indicated in Fig. 3 was arrived at.

The upper portion of the furnace is in appearance very much the same as an ordinary blast furnace. This shaft is built on a large crucible or melting chamber, B, projecting through the roof of which are three electrodes, one being shown at A. At the top of the shaft, there is, of course, a cover with a charging bell very much the same as on the present-day blast furnace. The gases coming off the charge at the top are led out at C to a dust catcher, D. Cleansed to a certain degree, this gas is blown by means of a blower, E, back into the crucible at F.

It will be noticed that the tuyeres by means of which the gas is blown into the crucible slant upward. This is for the purpose of allowing the gas to impinge against the crucible roof, thereby cooling it. This does not in any way lower the efficiency of the furnace, the heat absorbed by the gas in cooling the roof being given back to the charge as the gas flows upward again. Indeed it would appear to be a great factor in raising the efficiency, since the heat absorbed by this gas in the crucible would have otherwise been most likely lost by radiation. The tuyeres (three in number) by means of which this operation is performed, have peep-holes, as shown at L, so that the operator may judge the roof temperature, and accordingly regulate his jets of gas.

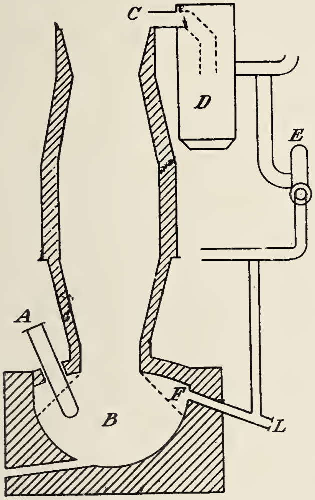


Fig. 3.

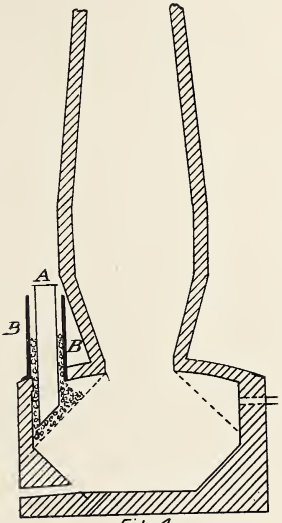


Fig. 4.

In this process there are no electrodes embedded in the walls of the furnace, the current passing between the three projecting carbons, thus giving intense heat in the crucible.

The Frick furnace, shown at Fig. 4, is somewhat similar in construction to the last furnace. A vertical shaft is superimposed upon a crucible, and through the roof of this lower melting chamber there project two vertical carbon electrodes, one of which is shown at A. These electrodes are suspended in casings or shafts, shown by heavy lines at BB.

The distinguishing feature of this furnace is the fact that the electrodes are packed around loosely with a reducing agent such as coke or charcoal. This coke or charcoal forms a protecting layer around the portion of the electrode in the crucible, and also intervenes between the electrode and the charge as indicated. (The dotted lines represent the slope of the charge as it works down from the shaft).

The purpose of providing this covering of coke or charcoal, as the case may be, is to protect the electrodes from being oxidized away. It can readily be seen that the carbon of the electrode would itself be oxidized if there should happen to be quantities of ore around the electrode. The reducing agent, however, protects the electrodes from being oxidized by entering into the reactions itself, and also since there is an intervening layer between the electrode and charge, there will be far less wear on the electrode, as the charge slides down.

There is also provision made in the furnace to carry the gas from the top and blow it back into the crucible if it is so desired. (References 6 and 7).

Electric Steel Furnaces.

Furnaces in which the refining action necessary for the production of steel may be carried on can be divided into two classes: (1) Induction Furnaces; (2) Arc Furnaces. The latter class can be sub-divided into furnaces in which the arc is formed between the electrodes above the bath; and those in which the arc is between the electrodes and the bath.

Furnaces of the induction type are constructed in such a manner as to make use of a well-known electrical principle which may be stated to suit this particular purpose as follows: If an alternating current be passed through a coil of wire known as the primary coil, and if there be surrounding this coil a second independent coil, there will be induced in this secondary coil, as it is called, an independent alternating current. In order to intensify this effect it is usual to wind the primary coil around an iron core.

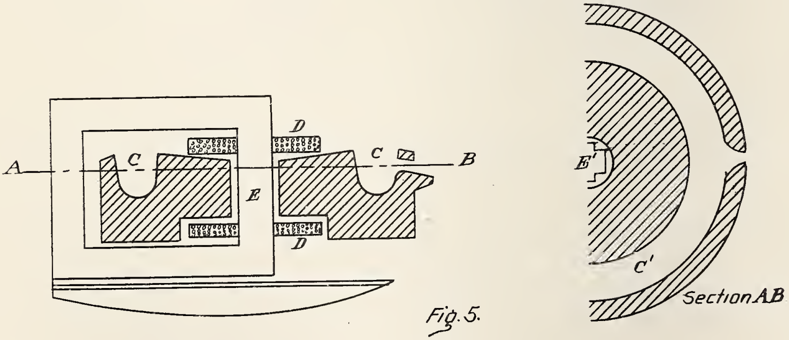


Fig. 5.

Fig. 5 represents two sections of one of these induction furnaces. At D and D are two coils of wire wound on an iron core, E. Surrounding this core is a circular channel, sections of which are shown at CC. If a horizontal section, AB, be taken, the channel will appear as at C′, surrounding the core E′. (Merely half of this section is shown).

If now the channel CC be filled with a charge of molten iron, there will be formed around the core and coils DD a closed coil of one turn; so that if an alternating current be passed through the coils DD, there will be induced in the molten metal another independent current. It is this induced secondary current that furnishes the heat in the charge forming the ring CC.

There are a number of these induction furnaces being used for the manufacture of high quality steel. The particular type shown diagramatically in Fig. 5 is known as the Frick furnace; but there are several other types, outstanding among which are the Kjellin and Röchling-Rodenhauser. In the Kjellin furnace, there is merely one long vertical coil around the core instead of the two flat coils as in Fig. 5. There are, of course, other differences, but the explanation given for Fig. 5 will apply to the Kjellin furnace, which has a channel around the primary coil for the charge. (References 5 and 11).

The Röchling-Rodenhauser furnace, while it is of the induction type, has a feature which is extremely novel. This furnace may be said to have two secondary currents, one of which is the usual current induced in the ring of metal as explained before. The other current has its source as follows: Around the primary coil is placed a secondary wire winding, the terminals of which are led to electrodes embedded in the walls of the channel for the metal. Thus there is induced in this secondary winding a separate current, which in passing through the bath of metal adds to the heating effect of the current already induced in the ring of metal itself.

Unfortunately, it is impossible in such a synopsis to go more completely into the details of these furnaces, but there will be found in References 5, 7 and 8 abundant information regarding the three types mentioned.

Passing to the arc furnaces, at Fig. 6 there is illustrated the principle of the Stassano furnace. Projecting through the walls of the furnace are three electrodes, as shown in the cross section. Between these carbons is formed an arc, A, the heat from which is radiated to the bath of molten metal B. The furnace, which is inclined, is given a rotary motion about its upright axis, thus causing a stirring of the charge. The regulation of temperature in such a furnace is under very easy control. (References 5 and 9).

Considering next furnaces in which the arc is formed between the electrodes and the bath, there are two types which seem to stand out pre-eminently, viz., the Héroult and the Girod furnaces, the principles embodied in both being easily explained.

Fig. 7 illustrates the method of making steel in the Heroult furnace. Suspended through the roof of the furnace are the electrodes A and B. The charge lies on the hearth and these electrodes are lowered till an arc forms between them and the bath. The current passes down one electrode, arcs to the bath, goes through the bath, arcs to the other electrode, and out again.

The upper cross section, Fig. 7, merely shows diagramatically that the furnace is so constructed to allow it to be tilted forward when the charge is to be withdrawn. The electrodes are held in position by braces attached to the furnace as indicated. (Reference 5).

The Girod furnace, while it is in outward appearance very much the same as the Héroult, differs from it in this respect. Embedded in the hearth of the furnace are suitable electrodes, and the current, instead of passing in and out from the top carbons as in the Héroult furnace, has a path from the upper electrode, or electrodes, through the bath to the connections in the bottom of the furnace. Thus instead of the upper carbons being in series, as in the Héroult system, they are in parallel. In actual operation, the current in the Héroult furnace passes along the slag, thus providing a very hot blanket as it were. In the Girod system, the current in passing through the bath itself gives, it is claimed, a method more suited to working from a cold charge. As against this is the counter-claim that furnaces with electrodes embedded in the hearth are troublesome to repair. Be all this as it may, there is the incontrovertible fact that both systems are now in extensive use. (See reference 10).

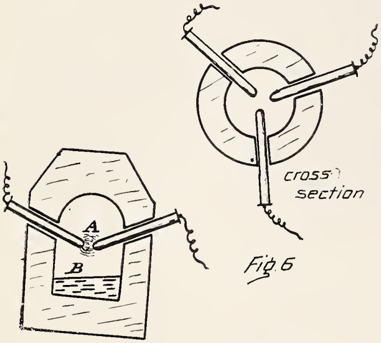


Fig. 6

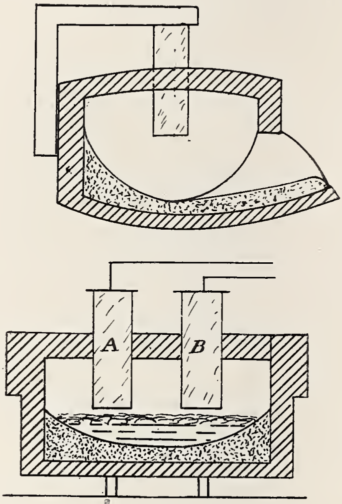


Fig. 7

In conclusion, it is interesting to note that not only are these steel furnaces being used to displace the old inefficient crucible steel plants, but there are notable examples where the larger fields have been entered. Quite recently the Prussian state railways have been buying rails from a firm manufacturing steel by the Röchling-Rodenhauser system. These rails when tested chemically and physically were of a much higher standard than the specifications called for. In the United States the Illinois Steel Company has lately been refining molten steel from the acid Bessemer process by means of a Héroult furnace. There are also other instances where the electric furnace is being used in combination with either the Bessemer or Open Hearth processes as will be seen in Reference 10.

In Reference 10, there will be found a tabulated list of steel furnaces in use throughout the world. It will be noticed that in most cases alternating current is used—mostly single phase—although direct current is sometimes used. The reduction furnaces described use an alternating current.

As to the actual working of these electric furnace processes, it may be pointed out that the regulation of the metalloids in the desired metal follows the theory of the ordinary processes, the main difference being that it is possible to maintain very much more basic slag.

SUMMARY.

The advantages of the electric furnaces, reduction and refining, may be stated as follows:

1—Efficient production of heat.

2—Ease of regulation as regards temperature.

3—On account of the high temperatures attainable, it is possible to maintain a very basic slag.

4—Absence of injurious gases in steel working processes.

5—The possibility of using charcoal as a reducing agent for making pig iron.

KEY TO REFERENCE NUMBERS.

No. 1—The Electric Furnace, Its Evolution, Theory and Practice (Alfred Stansfield).

This book contains a very concise and clear outline of the historical development of the electric furnace. There will be found in it a discussion of the relative costs of electric energy and fuel for producing heat.

On page 250, vol. 13, of the *Canadian Engineer* will also be found a discussion of these relative costs by the same author.

2—"Metallurgical Calculation," vol. 1 (J. W. Richards).

The methods outlined in this book are extremely good.

3—Report on experiments at Sault Ste. Marie, 1907 (Eugene Haanel).

These experiments were carried on by the Canadian government.

4—Application of the Electric Furnace in Metallurgy (A. Keller).

Journal of Iron and Steel Institute, 1903, vol. 1, page 161.

5—Report of the Commission appointed to investigate electro-thermic processes of smelting iron ore and making of steel (Eugene Haanel).

This is the most comprehensive report ever made on electric processes up to 1904, and is even yet invaluable.

6—Investigation of an electric shaft furnace, Sweden (Haanel).

7—Recent advances in the construction of electric furnaces, etc. (Haanel).

The last two reports published by the Canadian government are very complete.

8—Electro-chemical and metallurgical industry, vol. 6, pages 10 and 458.

Good descriptions of the Röchling-Rodenhauser furnace and its operation.

9—Same periodical as 8, vol. 6, page 315. This is an exhaustive article by the inventor of the Stassano furnace.

10—Stahl and Eisen, March 23, 1910, page 491.

This gives a tabulated list of furnaces in use. See also No. 7 for same thing.

11—A description of a Kjellin furnace will be found on page 397 of vol. 3, journal of Iron and Steel Institute.

PROSPECTING IN THE COBALT DISTRICT.

H. L. BATTEN, '11.

Prospecting covers a great many operations, from the search for, and staking of claims, to actual mining work underground. This paper does not deal with the search for claims, but is an attempt to give some idea of the work to be performed after the claim is staked, for the purpose of determining the value of the property, position and value of veins, etc. We are still left with surface prospecting and underground work to be considered, as both have to be performed in practically all cases before a property may rightly be called a mine. There can be no doubt that a thorough prospecting of the surface before commencing mining operations is of the utmost importance, and should be taken seriously. In spite of this fact there are quite a number of properties around Cobalt and South Lorraine with a shaft down 100 feet or more on a one-inch vein of calcite carrying no values, while not a shovelful of dirt has been moved on the other parts of the property. The cry is, "We have no money to spend on the surface, and besides, all the veins do not show on the surface." This is no doubt true, to a certain extent, but if we try to make out a list of paying mines around Cobalt that had no showings on the surface, we shall find there are very few.

Again, a great number of the properties that are supposed to have been prospected have never been prospected thoroughly. The work has been done in a haphazard manner by the original owners, or by men hired by them, as assessment work. The idea has been to put in so many day's work, and no successful prospecting can be carried out in this manner. For the work to be thorough, some system must be adopted, not necessarily to be blindly followed, without modifications, but to serve as a guide. Unless some method is adopted, trenching will not have progressed very far before the question "where to put the next trench" will arise. Again, if the positions of the trenches be determined before work commences, it will probably soon be found that a trench could be run, with much less work, a few feet to one side, and be of equal value for prospecting purposes.

The idea of surface work is to lay bare the bed rock, so that it can be examined. This is usually done by digging parallel and perpendicular trenches, thus dividing the property into a number of squares or rectangles. The distance between the trenches must be determined by the circumstances. The closer the trenches the less likelihood of veins being missed, but a great number of things have to be considered. If the surface covering is deep it may not be advisable to run trenches less than 200 feet apart on account of the expense. On the other hand, the Nipissing Mines intend to remove all the surface covering by hydraulicing.

It is obviously impossible to lay down any rules, as the distance between trenches must be determined only after considering all the circumstances; but on most properties probably about 60 feet apart would be a suitable distance. The distance apart will probably not be the same all over the property. It may be found after putting down a few trenches that, while part of the property should be prospected very carefully, the remainder may not show indications of being worth going to much expense over. No hard and fast rules can be laid down.

As regards the direction of trenches, the usual way is to run north and south, and east and west trenches. When no veins are known on the property, and the surrounding properties have not been prospected, these directions are as good as any, and are most convenient. However, it is a somewhat generally accepted rule that veins in proximity to each other are likely to be approximately parallel. The best direction, therefore, to run the first trench is perpendicular to a vein that has already been uncovered. There is almost sure to be such a vein, marked by a discovery post, and a start should be made at that vein. On a property prospected by the writer this last summer, one vein was known before commencing to prospect, striking approximately north and south. By running trenches perpendicular to this vein four others were uncovered, their strikes varying from north and south to north 50 degrees east. Thus the strike of a vein probably is an indication as to how nearly veins may be expected to run; but veins are extremely erratic, and are almost as likely to be found running in any other direction.

The first thing to be done in prospecting a property is to find out everything possible about it; assuming, of course, that everything possible has already been found out about the company working it. The boundary lines should be carefully and clearly marked out or a great deal of time will be wasted hunting up corner posts. The whole property should be gone over carefully, in company with a man who knows the ground, if possible. If time permits, a rough sketch map should be made, showing the relative positions of any veins that may be known, outcropping rock, swamps, or other places difficult to prospect, and as much of the geology as can be determined. If the timber has been cleared off, this work should not take long, but if the bush is thick a week probably can be profitably spent in this manner.

It is necessary to be fairly well acquainted with the property before deciding on the best way even to start prospecting, or where to start, so that the work may be put in to the best advantage. A little care and forethought can save money in prospecting as in everything else, and no start should be made until the whole claim has been carefully examined. There is always some doubt where to make a start. If the vein on which the discovery was made has not been stripped, three or four men (not more than four men can work to advantage, stripping a vein that has been uncovered in only one place), should be put on this job while the claim is being examined. This vein should be stripped for a sufficient distance to give a good idea of its value. If the indications are promising, it (and all the veins) should be stripped as far as it can be followed. However, as soon as the approximate strike has been determined, more men can be taken on and a trench started perpendicular to the vein; or approximately so.

The property will probably be divided naturally into several sections. The goal to be aimed at is to show results in the shortest possible time, and work should therefore first be done where the indications are best; or if there are no indications worth considering, a start should be made where the most bed rock can be stripped in a day. The section containing the vein should be the first to be prospected, and an attempt must be made to pick up any parallel veins there may be.

Contacts must be considered. If diabase outcrops in one place and Keewatin rocks in another, they should be joined by trenches, and the contact located. The reason for this is that there is a likelihood of veins occurring at or near the contact. In the case of the five parallel veins referred to previously, the first was at the contact of diabase and conglomerate, while the other four were all within 250 feet of the contact.

In working over the ground in sections however, care must be taken not to lose sight of the general method which has been adopted. Before the work is complete the trenches in the different sections have to be connected up, so that each trench runs from one boundary line to the line opposite. This may not be possible on account of a swamp or drift too deep to make trenching practicable, but should be carried out whenever possible.

Where heavy trenching is encountered it should be left until all the light work has been done, unless there is some special reason why it is desirable to put down a trench in that particular place. When to leave a trench (temporarily, of course), is a matter of judgment. As a general rule it may be said that all trenches requiring timbering should be left till the lighter work is finished. In the spring no attempt should be made to put down wet trenches—it is almost hopeless to try and make sure of missing no veins and yet make good progress with wet trenches. Also, it is impossible to make good footage with heavy or wet work, and it is most important to make a good showing at the start.

Before settling down to prospect thoroughly, section by section, the whole claim should be gone over by running a few preliminary trenches. This is especially advisable if outcropping rock be scarce. As accurate a map as possible should then be made, and on this map everything that is known should be marked. This map should be carefully made and brought up to date at least at every month-end. The positions of all trenches should be accurately shown, and the positions of all veins and test-pit marked. When a few trenches have been put in, the topography should be sketched in, and the elevations of all important points shown. The only instruments required are a compass and chain, and an aneroid barometer, for obtaining the relative elevations. This map is useful for several purposes. It can be seen at a glance what ground has been prospected and what remains to be worked, and the required positions of trenches to connect with trenches already dug can be determined. If the bush is thick these cannot be lined in by sight. Also reports on the progress made are greatly simplified by the possession of such a map. A tracing can be made each month-end, with each month's work shown in different colors, and handed in with a short description of any discoveries made. Such a report conveys more information and creates a better impression than a lengthy written account of the work performed.

There are a few points to be noticed regarding the details of the work, and one of these is the best widths for trenches. It must be remembered that a slight increase in the width of trenches means a considerable increase in the amount of dirt to be shovelled. Economy therefore, demands a narrow trench. In a narrow trench, however, it is very difficult to clean off the bed rock thoroughly. Three feet in width should probably be considered a minimum, and this width is sufficient only for trenches up to about three feet deep. A trench five feet deep should be four feet or four feet six inches wide on the surface, and deeper trenches, even if no timbers are required, should be wider still. The best width depends to a certain extent on the banks, so it is impossible to lay down any rules, but the general tendency is to dig trenches too narrow, which means difficulty in examination, and a consequent likelihood of veins being passed over unnoticed.

As bed rock is stripped it must be very carefully cleaned off. If the surface is dry sand or gravel, this is best done by brushing. If the soil sticks to the rock, as clay, for instance, does, the rock must be washed, and washed thoroughly. Care must be taken not to fill up the cracks and crevices with mud, as it is these which have to be most carefully examined. It is better not to wash off the rock unless absolutely necessary, owing to this trouble caused by the inequalities being filled with mud.

Trenches cannot be prospected too carefully, as especially in diabase, it is often extremely difficult to recognize a vein. The bed rock should be most carefully watched for any change in texture, as the rock near a vein is often finer grained than the surrounding rock. Too great care cannot be exercised, and every place where there could possibly be a vein should be shot out. The number of veins which have been found in old trenches, and which had previously been missed is startling.

With even the greatest care some small veins will probably be passed over, and a vein less than one inch in width in this district may be extremely valuable.

Having found a vein, the amount of work that should be done on it depends on the vein itself. It must at least be stripped for some little distance, and a test pit sunk deep enough to get below the weathered surface. If the indications are in any way promising it should be stripped and opened up as far as it can be followed, and the trench should be sufficiently wide to allow the vein to be shot out without having the banks fall in on it. A considerable amount of shooting is unavoidable when opening up a vein, but as much drilling as possible should be avoided, since it is extremely difficult to get a hole down to any depth owing to the number of joints and seams usually found near a vein, and even under the best conditions, drilling is a slow and expensive job. A vein can usually be opened up by exploding powder in the fissure (providing the loading and tamping be properly done). More powder will be used than with drilled holes, but the saving in labor more than repays for this.

Before reporting any find, care should be taken to be absolutely certain. If in very small pieces, bismuth and silver are easily confounded. When looking at museum specimens there appears to be little similarity between the two, but when silver is expected and a speck of bismuth encountered, it is very easy to be misled, in fact, it is often absolutely impossible to be certain without a chemical test. Cobalt bloom and red iron oxide are frequently confounded. Unless there can be absolutely no doubt a chemical test should always be made before any find is reported.

When the surface work is completed there are two methods of prospecting underground to be considered—the ordinary mining methods, of shaft-sinking, drifting and cross-cutting; and the diamond drill.

It can safely be said that the diamond drill has not been a success in this district, at least as far as the search for, and testing of veins is concerned. There are two principal reasons for this failure; first, as the drill passes through the vein the latter breaks up into powder, and no core of the vein-matter is obtained. Secondly, even when a sample of the vein is obtained, the information gained is of little value. Only one point in the vein is sampled, and while there may be no values or very low values just at that point, other parts of the vein may carry high values. Sufficient data to form any idea of the value of a vein cannot be obtained with the diamond drill.

Ordinary mining methods apply to shaft-sinking, etc., whether the property is a prospect or a mine. It is obviously impossible in this paper to go into such questions as to when a plant should be installed, or when to work by hand. Around Cobalt this question has been solved to a great extent by the advent of the power companies. In South Lorraine it still exists, although they are expecting to have electric power there this fall (1910).

It must be remembered that in prospecting, as in all mining ventures, no two propositions are alike. The work to be done depends upon so many things; the property itself, amount of money to be spent, the length of time in which to perform the work, and a host of other circumstances have to be taken into consideration. There is room for differences of opinion at every turn, and there is no pretence made that this paper is in any way complete, or even representative, it is simply a collection of a few opinions formed during a couple of summers' prospecting in Cobalt and South Lorraine.

GAS AND OIL ENGINE RESULTS.

Thermodynamic Laboratory, University of Toronto.

W. W. Gray, B.A. Sc.

A series of tests was conducted by a party of fourth-year students, Messrs. Schwenger, Stroud and Thompson, on the 9 B. H. P. Fielding and Platt gas engine, to determine its gas consumption per B. H. P. per hour at various loads.

The engine is of the single cylinder, single acting, horizontal, hit-and-miss governor type, and is of standard English design throughout. The results obtained are very satisfactory for an engine of this small power.

Results of Tests.

City illuminating gas.
Diameter of cylinder, 7 inches; stroke, 14 inches.
Compression, 90 pounds per square inch.
Ignition, electric, by trip magneto.

No. of test	1	2	3	4	5	6	7	8	9	10
Date	Jan 25	26	26	26	26	26	27	28	28	28
Duration (minutes)	40	30	30	30	25	30	25	30	15	30
R.P.M.	220	220	219	219	219	220	218	218	218	218
B.H.P.	0	1.19	2.03	3.04	4.05	5.08	6.04	7.06	8.06	9.07
Gas per hour, cu. ft.	51.2	91.5	86	93	114	121	150	153	166	182
Gas per B.H.P. hour cu. ft.		76.9	42.4	30.6	28.1	23.8	24.8	21.7	20.6	20.1
Ratio — Gas	1	1	1	1	1	1	1	1	1	1
Ratio — Air	9	6	10	10	10	12	10	10	10	10

This engine is provided with a special vaporizer and valve gear, to allow the use of kerosene, the vaporizer being kept at the proper temperature by means of a kerosene torch.

Ignition is by the hot tube method, the tube being heated by the vaporizer torch.

A series of tests at various loads was conducted on this engine by Messrs. Black, Manning and Taylor, a party of fourth-year students.

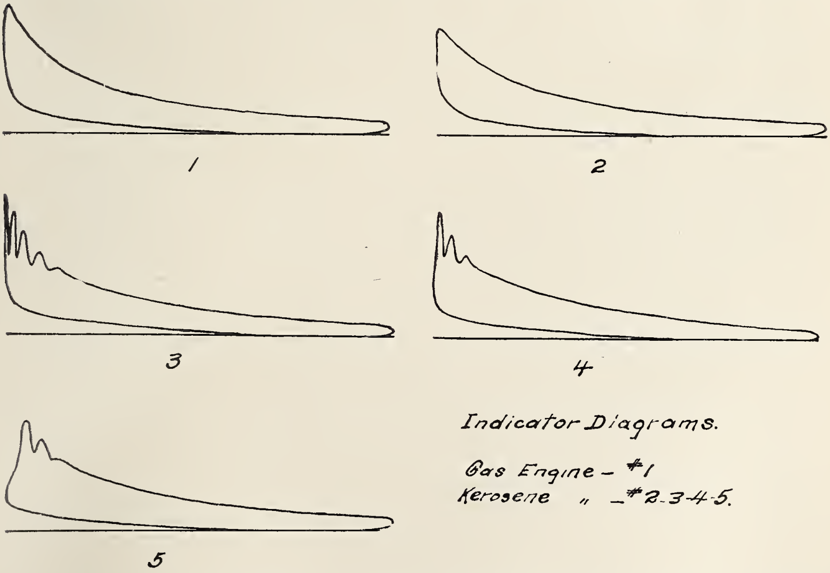
Results of Tests.

Fuel, kerosene.
Compression, 90 pounds per square inch.
Ignition, hot tube.

No. of Test	1	2	3	4
Date	Feb. 17	17	17	17
Duration in minutes	30	30	30	25
R. P. M.	213	220	221	212
B. H. P.	...	1.51	3.03	7.75
Kerosene per hour (lbs.) (Including Torch)	1.937	2.562	3.687	6.187
Kerosene per B.H.P. hr. (lbs.)	...	1.7	1.22	.8

Diagram 1, taken from the engine when it was operating on city gas, is a characteristic card for a gas engine.

Diagram 2, an oil card; is a very good diagram for an oil engine; very few similar cards were obtained during the tests.



Indicator Diagrams.

Gas Engine – #1
Kerosene " – #2-3-4-5.

To produce this diagram, the treatment of the kerosene must have been under ideal conditions, with respect to temperature of vaporizer, proportion of air and vapor in the mixture, and temperature of ignition tube.

Diagrams 3, 4, and 5 indicate too rich a mixture, a condition difficult to overcome in oil engine work.

NOTE ON THE UTILIZATION OF ATMOSPHERIC NITROGEN.

SAUL DUSHMAN, B.A.

During the last few years a large number of processes have been devised for the utilization of atmospheric nitrogen. The motives for these processes have been two-fold; both in fertilizers and in explosives nitrogen forms a very important constituent. Nitre or Chili saltpeter has been the substance chiefly used for these purposes in the past; but the nitre beds are gradually becoming exhausted, and the world has come to realize that some other source of fertilizers must be sought for if its food supply is to remain assured. At the same time there exists a continually increasing demand from the manufacturers of explosives, for a concentrated nitric acid.

As far back as 1776, Cavendish, the famous English physicist, discovered that an electric spark passed through a moist mixture of oxygen and nitrogen produces nitric acid, and at least three processes are in commercial operation which are based upon this reaction. In the process devised by Birkeland and Eyde in 1904, a 5,000-volt alternating current is passed between water-cooled copper electrodes and by means of a magnetic field at right angles to the latter, the arc is spread out into a disc of over two meters in diameter, thus causing almost the whole volume of air in the furnace to be raised instantaneously to a very high temperature. About one per cent. of the air passing through the arc is thus converted into oxides of nitrogen, which are then washed out by passing the gases from the furnaces through a series of towers. There is obtained in this manner a 50 per cent. nitric acid, which is converted into calcium nitrate by neutralizing with lime. The latter is used as a fertilizer directly. The furnaces used by Birkeland and Eyde were originally of 500 k.w. capacity, but subsequently they were replaced by 800 k.w. units, and at the present time it is the intention to replace these by 1,600 k.w. furnaces. In the first commercial installation at Notodden, Norway, only 1,500 k.w. was used; afterwards this was increased to 40,000 k.w. During 1908, the first year of operation, the total income was $536,000, and the net gain, $134,000. Plants have been established at numerous other places in Norway, where water-power is available, and according to most recent reports the Norwegian industry of manufacturing air nitrates is undergoing rapid extensions involving the expenditure of nearly $15,000,000. Not only calcium nitrate, but also more concentrated nitric acid, nitrate of ammonia, nitrate of potash, as well as sodium nitrate are being manufactured at these plants. One of the principal reasons for the success of the process in Norway is undoubtedly the small cost of power which is said to be available at about $5 per horse-power year.

Another process based upon the same fundamental principle is that developed very recently by the Badische Anilin-und Soda-Fabrik. "In this process a continuous arc is produced in a long tube by first bringing electrodes together and then gradually moving them along the tube while the other remains fixed at one end of the tube. The current of air, instead of being passed through this arc, is passed around it through the tube by being forced in at an angle to the main axis of the tube. It is said that the arcs used in this process vary from 35 to 50 feet or more in length, and are maintained continuously for days or even months at a time."

Besides these two processes which are both in successful commercial operation, there is a third process for the oxidation of atmospheric nitrogen which has been devised by H. and G. Pauling, and is working on a large scale near Innsbruck in Tyrol. The electrodes are curved like the electrodes of the so-called horn lightning arresters. The arc is started at the narrowest part between the electrodes by means of a special lighting device. The air current passed through the arc blows it out to a considerable distance and thus increases the volume of air heated to the extremely high temperature at which combination occurs. "The twenty-four furnaces at present installed in this plant have a total capacity of 15,000 h.p. Two other plants, each of 10,000 h.p., for carrying out the same process, are in course of erection, one in Southern France, and the other in Northern Italy."

The process of Frank and Caro for the utilization of atmospheric nitrogen is totally different from any of the above methods. Nitrogen is passed over heated calcium carbide and the result is the formation of a substance having the formula $CaCN_2$ and known as cyanamide. Investigations at numerous agricultural stations have shown that it can be successfully used as a fertilizer, and accordingly a large number of plants are being erected both in Europe and America for its production. The United States Cyanamide Company has a 5,000-tons works at Niagara Falls, Ontario, and is also building another plant in Tennesee. Cyanamide is also of interest on account of the number of interesting derivatives which it is capable of yielding when treated with different reagents. An important reaction is that with steam, leading to the formation of ammonia, which may be subsequently converted into ammonium sulphate.

Still another method for the utilization of atmospheric nitrogen has been devised recently by F. Haber and patented by the Badische Anilin-und Soda-Fabrik. A mixture of nitrogen and hydrogen in the required proportions is maintained at a constant high pressure and heated in presence of a catalytic reagent (such as finely divided iron or osmium) to a temperature which varies between 400° and 800° C. Only about 8 per cent. of the mixture is converted into ammonia, but the power necessary for the compression and circulation of the resulting gases is very small, and it appears very likely that in the near future this process will be exploited industrially.

TECHNICAL EDUCATION

A Synopsis of the Discussion at a Meeting of the Engineers' Club, October 13th, 1910.

Dr. Galbraith, *Dean of the Faculty of Applied Science and Engineering.*

Mr. Chairman and Gentlemen:—The object of having a discussion on this subject by the Engineers' Club is for the purpose of presenting some of our views to the Royal Commission on Technical and Industrial Education. Thinking that the members of the club might have some ideas on this subject which they would like to present, I asked the Commission if they would care to receive our views. They assured me that they would welcome such opinions, and would be glad to receive them upon their return to Toronto for the examination of witnesses.

To-night I am asked to open the discussion, and do not propose speaking longer than is necessary to present the question and to elicit the opinions of the members of the club who are present.

The term "Technical Education" is very broad, so broad indeed, as to be almost vague. The Faculty of Applied Science in the University of Toronto, covers only one branch of the subject, and it may be the duty of the Commission to study the question in its most general sense.

The name is almost a misnomer, as usually applied. The word "technical" really means, "relating to the art of making things or doing things"; for example, a trade education in the methods of making things or the doing of work by manual labor is technical in the original sense of the word. The expression is now applied generally, to training in practical science.

As an illustration of some of the difficulties in technical education, if you turn to the curriculum of the Toronto Technical School, you will see that very nearly the same subjects are taught in the evening classes as at the University in the Faculty of Applied Science. A stranger, not knowing the circumstances could not make any distinction. Now, the difference is this: the objects of the Faculty of Applied Science are well defined: they are limited by the nature of the professions to which the training is directed, and consequently, it is comparatively easy to construct the curriculum. But in the case of the municipal technical school, the students come from all sorts of positions and trades. They often have no definite object in view. One desires one thing, another wants something else. It is hard to determine what to include and what to leave out, and this is due to the fact that the requirements of the students vary. They cannot be divided into graded classes as are the students in the Faculty of Applied Science. They require to be treated as individuals rather than in classes.

Another difficulty is this: in the university (I am not speaking of Toronto only, because the principles apply generally), the matriculation, or entrance examination, whatever its weaknesses may be, accomplishes one object. The students know at the beginning, and the teachers know, just what the qualifications of the students are. The instructor knows where to begin, and this in itself is a great advantage. In the evening classes of the Technical School the situation is quite otherwise. Satisfactory grading by means of an entrance examination is difficult or impossible. These difficulties in the case of the evening classes came under my observation when a member of the board of directors some years ago.

The teaching of trades in the municipal school in a place like Toronto is rendered difficult by the great number of trades to be considered; the cost would be enormous. Again the problem is made more complicated by the attitude of the labor unions. The representatives of the unions at the time I speak of were in favor of teaching practical science, but opposed to teaching trades. The problems to be solved in the case of the Toronto Technical School will be the problems of the municipal technical schools in the majority of Canadian communities.

There is a noteworthy movement that is taking place in America, viz., the teaching of the trades by the people who are most interested in them. This seems only common sense. It is being done by the larger corporations; the Grand Trunk Railway, and the Canadian Pacific Railway have begun this work in Canada. They have their own schools for their apprentices, who receive instruction in both the theoretical and the practical sides of the trade, and the results are very encouraging. The instruction books used by these corporations are very well adapted to their purpose. While a man is working on one machine, he is given a blue print describing the machine to be taken next. He studies this, and is able to answer theoretical questions relating to the machine by the time he is moved on to it. This plan is being used also, by the Baldwin Locomotive Works, in Philadelphia, and in many other large plants. It is adopted by a number of the largest corporations, and is done for purely business reasons. There is no philanthropy entering into the question, for corporations have no souls, and only work for the dividends. In these corporation schools there are two classes of students as a rule, viz., the men from the universities and the men with only a common school education. The trade education of these men, while extremely practical in both cases, is different, for the reason that they are needed for different purposes.

Much the same system obtains in Germany. The cases of which I have heard are in the manufacturing works in which applied chemistry is the fundamental science. The laboratory is located in the works. The best trained men are taken from the technical high schools and placed in these works, where they are trained in the methods of the company. It seems that where the employee is trained by the employer the result is mutually beneficial. It is not like the training of a group of men for something they may never follow afterwards.

There is not much respect shown by students for a teacher, whether in theory or practice, unless he is an expert in what he teaches. If we are to make any progress in the teaching of trades, we must have men who are skilled in the trades they propose to teach, and these men are what the Grand Trunk and Canadian Pacific Railways have. They have also practical men who can teach the necessary theory.

To obtain teachers with suitable qualifications will prove one of the greatest difficulties in teaching trades. I believe some teachers can be obtained in Canada. I know that among the young men who enter the Faculty of Applied Science there are some expert mechanics, and these men when they graduate may be used as teachers, since they would be equipped to teach both theory and practice, and could hold the respect and interest of the pupils. But not every graduate in mechanical engineering could do so, because as a rule, when he graduates, he is neither an engineer nor a mechanic. The difficulties of obtaining teachers for trade schools will naturally be greater at the initiation of the work than afterwards; demand will doubtless encourage a supply.

I have now touched upon a few of the leading points as they occurred to me. I have not gone into details, but have attempted rather to present the subject to the Engineers' Club in such a manner as to suggest questions for discussion.

Mr. R. W. King, *of Robert W. King and Co., Architects and Engineers, Toronto.*

I would like to emphasize one point made by Dr. Galbraith, which is, the absence of localization in the different industries. This has been one great difficulty confronting technical education.

I had an opportunity of seeing this in connection with the trade of knitting. There are certain centres given to this trade. In England it is Leicester. Weaving had a centre at Nottingham, while in Germany there were other centres for these trades. In Leicester and Nottingham and in some of the other centres, trade schools and technical schools are to be found, because there is where the industry flourishes. The government makes grants to these schools with a view to an increase of the staff. Germany set the example by instituting an immense school where trades desired by the community were taught. Its students were taught how to do their work intelligenly. This was the sort of education that England found it necessary to adopt, and they sent their teachers over annually to get pointers. I have no experience outside the fabric industry, but I would be especially interested in seeing the experiment tried in that line.

I suppose the same would apply in other parts of the country where these centres exist. In Ste. Hyacinthe, Quebec, there is a centre for woollens and knitted goods. In Ontario we have Paris. Now, if we are going to follow the example of the Old Country, it is in such places that the technical or trade schools, should be placed, and maintained by the government, I believe it would be to the advantage of the country to centralize the trade. You could not hope for much success in Toronto, I fear, because of the great variety of trades being followed.

C. H. C. Wright, *Professor of Architecture, Faculty of Applied Science.*

Dr. Galbraith has given you the academic side of this question, and I do not think that I can add anything to what he has so ably said. I believe that if the Manufacturers' Association deem it necessary to place their notes before the Commission on this subject, then the members of this club should also present their views; and I would like to hear what difficulties exist to you. What are your difficulties as practising men? Do your mechanics, machinists and artisans understand your instructions? Do they read the drawings, or do they blunder through them, making mistakes that cause endless trouble for you and for themselves? I would like to hear what these troubles in handling men arise from. I am not prepared to say that we have missed the cue, educationally, although there may be improvements necessary. We should know what the real difficulties are, the existing conditions, so that we can work together to clear them out of the way. I believe you men who are out in the practising world are the ones who have met the difficulties, and these are the things that I believe should be brought before the attention of the Commission.

T. Aird Murray, *Consulting Municipal and Sanitary Engineer, Toronto.*

I have been asked to give in a few words my ideas as to how far and in what way methods of education can be outlined to produce what is technically called a " Sanitary Engineer."

I understand that views expressed to-night are to be laid before a commission whose business is to report upon technical education.

My difficulty is at once apparent. I am not sure as to the exact classification of a " sanitary engineer," whether it should be "technical," "practical" or "scientific." But surely when we consider the point, does not this difficulty of definition apply all around? I cannot see that there can exist any such separate thing as technical education, no matter how much we may have got used to the term, as applied to those forms of education which are calculated to produce the man who actually performs. The theory, or principle, of equilibrium has always appealed to me as something of a natural force, producing the maximum efficiency. Therefore I do not ask, "Is a man technical?" "Is a man scientific?" or "Is a man particularly this or particularly that?" But I do want to know, are his actions based upon deduction or are they merely instinctive? The principle of deductive thought as separate from instinctive thought, appears to be the main quality distinguishing the so-called "human" from the general "animal" class of creation. Now, how can a man be "technical," as apart from "instinctive," unless his technical effectiveness is based upon deductive formulae.

It is useful that a man should knock a nail skilfully, truly and with precision, but if the action is controlled only by the instinct which causes a bird to build its nest with precision, he is no more than an instinctive animal. The man should, at the back of each knock, feel and know all the reasons and accumulative evidence which make for what is termed efficiency in work. Absolute efficiency in production is found in machine results; machine termination is the result of scientific application. The man must be superior to the machine; and must, therefore, be something more than a tool capable only of producing technical results.

But what has this to do with sanitary engineering? Simply this, you can no more make a purely efficient technical sanitary engineer than you can make a purely efficient scientific sanitary engineer. The efficient product must represnt a combination, and must result in equilibrium. This fact is being recognized in older countries. The United States of America in their universities, and European centres of research work as exemplified in the Hamburg State Institute of Hygiene recognize sanitary curriculums. Generally speaking, apart from the special sanitary engineering course at McGill University, nothing is doing in Canada. What is the result in Canada? We see, whenever an expert is required to advise on sanitary matters, an outsider called in. We train men in the problems of surveying and laying out a new country, in railway work, bridge building, and all the requirements of transportation, in fact, in everything of a utilitarian nature, even to the harnessing of our rivers for power; but in the maintenance of ourselves in a normal state of health, not only in health, but in a mere state of existence, we have no curriculum of training.

I have used the term "a mere state of existence," because one fact stands out plainly (all who run may read), a population cannot grow beyond the available water supply at the rate of at least thirty gallons of potable water per head per day. Apart from our ideal and practical thought of dominion, our calculations of serial production, our schemes of railway development, grain elevators, and multitudinous efforts and methods of transportation and inhabitation, no two people can exist, and no community can grow beyond " available water supply."

Here comes in the " sanitary engineer," the man who can weigh up both physical and chemical data and draw deductions, and tell a community just how far it can grow, and where it must automatically stop. Now what does this mean from the sanitary engineering educational point of view? It means a man trained not only in taking levels, making surveys, measuring quantity and estimating the cost of work, but in estimating the amount of character of available water within a given area.

This takes in a great deal more than what is generally called "technical engineering." The character of any water, apart from its quantity, is surely most important. Underground water is not only water, but is also a mixture and chemical compound or compounds; its constitution depending upon the absorbed and soluble quantities of foreign matters taken up from strata. Surface water, in its constitution as far as admixture appertains, is dependent upon the absorption and mixtures of forms of vegetable growth and decay.

Water, as generally found, is, in fact, not water as represented by H_2 O. in our text books, but presents other and more intricate chemical formulae, sometimes inorganic, sometimes organic, generally a combination of both, but seldom water.

Now the conclusion of the above is simply this. Certain defined lines of education are required to include a curriculum of training which will produce not only a so-called " technical man," or man who can measure a quantity and show how the quantity can be delivered, but one who can also determine the exact quality of the quantity in its relation to public health. Such constitutes the true definition and training of a sanitary engineer in at least one of the aspects; I maintain that this definition holds good throughout. To put the matter in a nutshell, in a light plain to everyone, I would ask the question, " Where can I get the man trained in Canada as an engineer, who, if I put before him an analysis of a peculiar liquid or sewage, could produce on paper another analysis and show the cost and method of obtaining a defined change? I can get plenty of men from the schools who can do mechanical drafting or instrument work, but the man who can think and deduct from natural phenomena are few and far between.

Now, natural phenomena is not a hidden basis of action, but is the hypothesis of all formulae. Therefore, I consider that technical education should be based upon this ultimate basis of things. If I were asked to generally define the lines of education for a sanitary engineer, I would, by simply stating that there should be added to the general engineering course, a course in organic and inorganic chemistry, together with a knowledge of bacteriology as affecting the transmission of what are generally termed water borne diseases, as well as affecting the various fermentation processes for breaking up organic compounds.

There are times when one has to listen to sentiments of depreciation applied to scientific men particularly, and to such phrases as " an ounce of practice is worth a ton of theory." All attempts to separate theory and practice are vain and foolish, and are the products of primitive ignorance. It is well to remember that the scientific man may be apt to know, while the other is apt to guess.

All that I have said up to the present may apply to the sanitary engineer, but I am inclined to think that the work of the Commission appertains to an enquiry more into the fitness or possible fitness of the man who may be employed by the engineer to execute or carry out his plans. The man who receives instructions and has to technically carry them out forms the material with which the Commission may have particularly to deal. This man cannot efficiently be produced by any method of any education apart from apprenticeship and practice in the particular line of work.

Sanitary engineering demands a host of so-called " technical men." The man who can actually go into a sewer trench and make a really watertight joint, or a lead joint in a water main, the efficiency of both sewerage and water supply depend almost entirely upon this man. In Great Britain we have associations of managers of waterworks and engineering installations which include so-called technical men, and who are simply the product of a demand. It strikes me that, after all, the law of demand and supply is the first cause instrument which produces the technical man, and his efficiency depends greatly upon the extent, character and amount of work which falls to his lot. The efficiency of the tool is in proportion to the efficiency demanded of the tool, and this simply brings me back in a circle to the point at which I started. The efficiency of technical work, if the product of deductive reasoning as apart from instinctive, depends upon the general and all-round training of the man who originates and who has the power to direct completion.

A. H. Gregg, *of Wickson and Gregg, Architects, Toronto.*

I hope to see something done, not only for architectural students, but for the trades that come closely in contact with the people. To my mind the great difficulty is that the people lack interest in the trades they are following.

An example of this was brought to my attention recently. A printer in this city received a large order for books and found it necessary to engage nine additional printers. He had to discharge the nine men almost at once because he found that they lacked sufficient knowledge of type-setting. Now, it would seem a strange condition of affairs that these men actually lacked such an essential qualification of a printer.

A short time ago we were building a manufacturing plant in which we had to have a small power plant. One morning I went there and found that one of the plumbers had prepared a complete drawing of the principal apparatus, showing the location of every valve in it. This man had done so merely because he loved his work and had been taught to think.

Now it seems to me hopeless to try to teach men their trades unless they can be first taught to think. Their education should be brought to the point where they can reason out their work.

The printer I have mentioned told me that they could not get apprentices to stay, because their life was made miserable by the journeymen. In the profession of architecture we are in a peculiar position. For ages the architect had been trained very much as we read in "Martin Chuzzlewit," where Mr. Pecksniff, having received the pay for his instruction, turned the student loose to draw the cathedral, or what he pleased, allowing him to be his own master. Things have changed to-day. The larger offices are run on business-like methods. Few of the large offices, however, care to take on a man to teach him. They do not wish to be bothered with him. They do not think this the proper place for a student. It seems to me to be the business of the people to train architects, because there is nothing that comes more directly in touch with the citizen than the work of the architect. Evidently the government should take an interest in this question. It certainly is a point that should be brought to the attention of the Commission.

L. V. Redman, *Department of Electro-Chemistry, Faculty of Applied Science.*

Dr. Galbraith has pointed out that education could be theoretical sometimes, and sometimes practical; while under certain conditions it could be both theoretical and practical, but unless the practical could be well taught, it had better be left out. In this connection I might mention Professor Duncan, of the Kansas State University, who started a department in connection with that institution, the results of which have exceeded even the greatest ambitions of the founder, although the department is but four years old.

The idea is this: A graduate of the university enters the employ of some large manufacturing concern, in the field of research work. He continues using the laboratories of the university, and devotes a certain portion of his time to the problem they have set him. His other time is devoted to the teaching of undergraduates of the institution. A certain fixed sum is given him as a salary by the concern, and a bonus is also given him if he solves the problem upon which he has been working. One such man found the process of making what is known as salt-rising bread. He isolated the particular culture that was necessary to make the yeast. As the consumption of this class of bread reaches a value of approximately four hundred thousand dollars per year, and as the discovery was made at the expense of about fifteen hundred dollars, the results are indeed worthy of special note.

Another man worked on the caseins present in butter for the interests of those engaged in the shipping of large quantities of butter. He discovered a process which will net for his company the sum of one thousand dollars a day.

Hence it might be well to consider such a scheme in connection with our university. The man would be no expense to the university, except for the room he would require to work in, and the possible discoveries made by him would offset this. It seems to me that it would be a good investment, both for the university and any large company that employed such a man.

C. R. Young, *Department of Applied Mechanics, Faculty of Applied Science,.*

Those in need of technical training may be divided into two classes: first, the professional class, composed of men destined by natural gifts or other advantages to occupy positions of large responsibility, and, second, the skilled laboring class.

From the fact that the representatives of the first class, viz., the practising engineers, or the engineer-managers, as they may be called, are occupied to a large extent in dealing with men, and as their power extends, to a less and less extent with things, the preparatory training for such should be essentially broad in its character. For this reason it is possible to train men to enter all branches of engineering at a single technical college.

The skilled workman is essentially a specialist, since proficiency in the handling of tools or in the carrying on of complex industrial processes is attained only after years of practice along a single line. It is even said in this connection that the difference can be noticed between a workman who has only his own experience behind him, and one whose ancestors for generations back were engaged at the same occupation. The skilled operator or workman, therefore, requires special instruction in the particular craft which he is to follow, and a technical school, to be of most value to him, must be most capable of affording assistance in his own branch of work. In this respect the training for skilled workmen differs essentially from that found most satisfactory for engineers.

A very important service which technical education may perform to assist the engineer in the conducting of his operations is to provide special instruction to those whose duty it is to carry his orders into effect. No one knows better than the engineer the difficulties encountered in avoiding errors of all orders of magnitude in the progress of engineering works. Sometimes this is due to carelessness, but most frequently to the inability of those engaged upon the work in the field to grasp the purpose and intention of the engineer. It may be due to lack of familiarity with plans and specifications, or inexperience in field operations, but the most serious errors arise from ignorance of the simple natural laws upon which the work is based. Thus, to cite actual instances, a contractor's foreman may place the vertical reinforcement of a retaining wall in the centre of the wall rather than at the back, or main reinforcement for a concrete beam at the top instead of at the bottom, and an inspector may quite as innocently decide that anchorages for the posts of a windmill tower are uncalled for, since the legs are battered, or that a form is capable of sustaining as much green concrete as can be dumped into it. As a means of lessening the likelihood of such errors as these, any arrangement by which contractors' foremen and inspectors on engineering or building work might receive elementary instruction in mechanics would be welcomed. At present the only means of this character generally available are afforded in the courses of the correspondence schools, but these can never equal personal instruction in efficiency.

T. R. Rosebrugh, *Professor of Electrical Engineering, Faculty of Applied Science.*

About twenty years ago I had brought to my attention a case which would be quite different in Toronto as regards the trade school, I refer to an institution in New Jersey, where there were but two industries engaged in—making of locomotives for the boys, and the silk industry for the girls.

It seems to me that the weakness of the present system is due to the separation of the two classes; the men brought up in the trades, and the men educated for professions at the universities.

I had some conversations some time ago with an engineer in charge of a large mechanical industry in this city, and he told me that it was next to impossible to get intelligent young men who would take an interest in some of the trades, for example, in foundry work. He thought it would be a great opening for any young man to devote himself to such work, and become a leader in that line.

Regarding the school system, it would appear that the child's time is considered as a by-product, something to be treated as having little value. If it were possible to include in the studies a few things that would be of vital importance to the young apprentice, at the same time allowing a good sound knowledge of the English language, no doubt much of the time spent in lengthy parsing of verbs could be devoted to instruction that would help the boy in the trade work of after years.

BOOK REVIEWS.

Heat Engines (being a new edition of "*Steam*") by William Ripper; Longmans, Green & Co., 1909; cloth.

The character of this little work of some 312 pages is fairly well set forth in the preface where the author states that it "has been written as an introductory text book for the use of engineering students, and more especially for those who already have some practical acquaintance with the manufacture and use of machinery." It originally dealt only with steam machinery, but the present edition includes internal combustion engines as well.

The whole problem of the production and use of steam is dealt with in a very elementary way, beginning with the general effects and transfer of heat, the properties of steam, and passing on to the steam engine. The various parts and accessories of a steam engine, including the details of the machine itself such as the valve gear, the crank, cylinder, governor, etc., are then discussed along with the various types of condensers in use.

The compound engine is treated with a fair degree of completeness. One might have expected a somewhat more complete treatment of the indicator than has been accorded it, but as the book is intended to be introductory, probably no more space could be allotted for this purpose.

The chapters on the boiler and combustion are well arranged to give a knowledge of the conditions of combustion and economy.

The last two chapters deal with the steam turbine and the internal combustion engines, and the book concludes with a series of helpful questions bringing out the essential features of the various chapters. On the whole, the book is well illustrated, and should serve as a very good treatise for the beginner, and should also be helpful to the practical man. A number of problems are worked out through the book, and they are all put in such form that a knowledge of arithmetic is sufficient to understand them completely.

Reviewed by R. W. Angus, B.A., Sc., Professor of Mechanical Engineering.

C. M. Canniff, '88, has entered into partnership with Mr. John S. Fielding, as Fielding & Canniff, civil engineers, 15 Toronto Street, Toronto.

J. W. R. Taylor, '08, is in the employ of the William Hamilton Co., Peterboro'.

W. G. Swan, '05, is divisional engineer for the C.N.R., near Vancouver, B.C.

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THE PURIFICATION OF PUBLIC WATER SUPPLIES.

T. AIRD MURRAY, C.E., M. Can. Soc. C. E.

Professor Hyde in a recent report upon a water supply for Sacramento, assumed that the question of quantity was of much more importance than the question of quality in the first instance. It is taken for granted that, no matter what the quality may be in the raw state, as long as the quantity is sufficient to meet all future wants, the eventual quality can be guaranteed by the adoption of purification methods.

Now this assumption as a basis for a report on a probable water supply has only been made possible of late years. Custom was at one time to insist upon an analysis of any probable water supply, and on the strength of that analysis to either accept or disregard it. This custom, however, is now subject to certain qualifications.

We know that no community can grow beyond its available pure water supply. Pure water is an absolute necessity to a community. If we have an island containing no potable water, no man can exist on that island. If there is only water for one man, then one man only can exist, and so on. No matter what latent wealth that island may contain, without potable water or the means of delivering potable water, that wealth is useless.

So in Canada where we have great areas of land wealthy almost beyond measure in productive fertility, the realization of such wealth is subject to the supply of potable water. There are town sites on the prairie which can never become practically more than town sites; there are villages which cannot become towns; towns which cannot become cities, and cities which cannot grow beyond a limited population, because of the fixed quantity of available pure water.

At the present day the amount of available pure water is much greater than it was, say, ten years ago; because we now know of efficient means by which impurities either inorganic or organic can be removed from water, and so water which at one time would, on analysis, have remained condemned may now be classed as potable. This is the meaning of Professor Hyde's assumption. We can now go straight for quantity leaving the question of quality to be taken care of as an afterthought. This does not mean that quality has no bearing on the choice in the first instance. It only means, as it did at Sacramento, that although a pure ground water supply existed in territory to the south east of the city estimated at 20 million gallons per day, that Hyde advised the city to pump from a polluted river source with an unlimited supply which would meet the probable growth of the city. In fact, the original pure water supply would have limited the city growth, whereas the abundant originally impure supply satisfied an unlimited city growth. A few years ago the growth of Sacramento was limited, by means of our newer knowledge of treating impure waters, its growth is now unlimited.

As to the modern requirements of a pure water supply, allow me to quote from Hyde's report above referred to:—

(a) The supply must be abundant and unfailing.
(b) The water must be free from pathogenic germs.
(c) The water must be free from those allied organic forms which may not as yet be recognized as accompanying disease, but which may, nevertheless, not be conducive to health.
(d) The water must not be discolored.
(e) The water must at all times be free from taste and odors.
(f) The water must be uniformly clear and free from turbidity, both that which may be produced by suspended mineral matters and that which may be due to suspended organic impurities.

To the above may also be added that water should not contain more than 15 degrees of total hardness and 5 of permanent.

It is very difficult and rare to obtain water which meets all of the above requirements. Settled large basins of water present the nearest approach to the ideal. Almost all rivers, whether pathogenically polluted or otherwise, are apt to present turbidity at times. Spring waters, though free from turbidity and generally pathogenically pure, are apt to contain the salts peculiar to the strata in which they are found, and are hence generally excessively hard, and at times even unfit for domestic use unless artificially softened.

It will be impossible for me in the limited time at my disposal to treat of methods for removal of all forms of impurities from water. I intend, therefore, to confine my remarks more particularly to methods and principles applied chiefly for the removal of pathogenity.

Filtration has been and remains the most generally accepted method of purifying water. We know that water in passing through the surface layers of the earth very quickly loses all trace of original organic impurities, and the only impurities it may contain must be new ones picked up by contact with the earth. It is, therefore, apparent that if we can artificially reproduce and improve upon the best conditions which exist in earth surface layers, we shall produce a method of water purification. That method has been evolved in the system called "Slow Sand Filtration." There is nothing of a mysterious nature, nothing of a complicated chemical character, takes place with slow sand filtration. The whole process simply amounts to a method of straining. There are certain engineering features connected with the regulation of the water as applied; but beyond these, the filter is simply a bed of sand of a given area and thickness capable of allowing a given quantity of water to percolate from the surface to the underdrains. The filters are subject to constant saturation, and are worked with a depth of water covering the whole surface sufficient to overcome the friction produced by the sand. The quantity of water which can be dealt with daily varies from 1¾ million gallons to 6¾ per acre, depending upon the quality and character of the raw water and the size of the sand grains used.

We have said that the whole process is simply one of straining. Thus, it differs almost entirely from the sewage filter, the object of which is not only to strain or hold back, but also to bring about certain chemical changes in the filtrate. Sand filtration does its most important work on and in the surface layer to a depth of about one quarter of an inch. The sand pores are not sufficiently fine in themselves to effectually keep back bacteria. The first few days' working of a sand filter is practically useless as a means of removal of pathogenic impurities; but as a scum of matter, deposited from the water, forms a carpet over the whole surface, bacterial removal efficiency increases to almost 100%. This scum formation is the peculiar feature which gives to slow sand filtration its unassailable position as the best mechanical method of removing pathogenity from the water. Like all human contrivances, however, it has its drawbacks. Chief of these is, that the surface scum continues to thicken until it becomes almost impervious and must be removed. Covered in sand filters average in cost on this continent from fifty to sixty thousand dollars an acre and to this must be added cost of pumps, pipe connections and all the other necessary appurtenances. The cost of operation ranges from two dollars per million gallons at Mt. Vernon, N.Y., to almost six dollars at Lawrence, Mass.

Slow sand filtration has been termed the English system of treating water. It has been adopted largely in Europe and latterly in the United States, and is now being installed in connection with the water supply of the City of Toronto.

It may here be said that the introduction of water filtration has universally been followed by a marked reduction in the so called water borne diseases, especially in the typhoid rate. At Hamburg the typhoid death rate averaged 47 per 100,000 for the five years previous to the installation of filters, and only 7 for the five years following. At Zurich, before the introduction of filters the typhoid death rate was 69 and after filtration 10. At Lawrence, Mass., the figures were 113 and 25 under similar circumstances. At the present time over 30,000,000 people throughout the world are being supplied with filtered water, more than one third of this number being in Great Britain. London, Liverpool, Birmingham, Leeds, Sheffield, Dublin, Leicester, Newcastle and Edinburgh are among some of the large cities in Great Britain using sand filters. In Europe we have Hamburg, Berlin, Breslau, Chennitz, Madenburg, Altona, St. Petersburg, Warsaw and Antwerp, where such filters have been in successful operation for many years. There are also similar plants at Calcutta, Bombay, Agra, Shanghai, Hong Kong, Tokyo, Yokohama, Osako and other cities. In the United States there are slow sand filters at Philadelphia, Pittsburg, Washington, Albany and many other places. In Canada there is one plant at Victoria, B. C. The typhoid death rate for Canada is 35 per 100,000, for European countries 16.

Slow sand filtration is an effective method of purifying water. It is costly both in construction and operating expenses. It requires exact and careful management; this applies to all methods of water purification. A bacteriological laboratory should be run in connection with the plant. It is in every sense more suited to wealthy and large communities than to small.

There is another form of filtration more distinctly American called "mechanical" or "rapid filtration." This system at once appeals to the layman because of the small space it occupies. Whereas slow sand filters will treat on the average 2½ million gallons per day, rapid filters average 120 million gallons per day. The sand used is coarse grained, and efficiency in purification depends not so much upon the filter itself, as upon preliminary sedimentation accompanied by the use of a coagulant. The filters are generally installed in units equal to about a hundreth part of an acre. High purification efficiencies are obtained by technical care in regard to proper working and the scientific application of the coagulant. Generally speaking the bacterial removal efficiency is below that of slow sand filters. The makers, and there are many, do not as a rule guarantee a removal of more than 97% of total bacteria, whereas 99%, and over, removals are looked for with slow sand filters. The temptation to use mechanical filters in this country is very great, as they can be installed easily in a building in connection with the pump plant and so guarded from severe frost.

With reference to the use of a coagulant I will quote from a report of the "Joint Special Committee to examine and report relative to the pollution of Water Supply, and the best method of filtration", City Document No. 15 of the city of Providence, R. I., as follows:—

"If the diameter of matter floating about in water is much less than that of the interstices between the grains of sand composing the filter bed, such matter, except as much as is caught upon the sharp edges of the quartz, will go right through the filter with the water.

"Now, if a substance could be introduced, drop by drop, into the water before it comes to the filter bed, which would have the effect of curdling the matter together, so that every one hundred or so of the smaller particles were made to join together and become one large particle, much as vapor or steam is condensed into drops, it would follow that they would be caught and held from going through the filter. This is accomplished by adding alumina (alum) to the water as it flows to the filter.

"The amount required is from almost none at all to about three quarters of a grain, according to the state of the water, say, an average of from one quarter to one half grain per gallon in the ordinary condition of the Pawtucket River water.

"The action is the same as when coffee is cleaned by means of the white of egg. No white of the egg goes to the drinker of the coffee—it is all drained off with the grounds; and as no alum goes to the drinker of the water, it unites with the impurities in the water and settles in feathery flakes of insoluble hydrate on the top of the filter, and is washed out with its accumulation of impurities when the filter is cleaned.

"The analysis of the purified water shows no trace of the alumina used, while the analysis of the wash water shows that the alumina is all washed out with other impurities. This feathery bed of precipitate flakes produced by the alum forms a filtering media of insoluble mineral matter which is well nigh perfect in its character. Bacteria are like the very fine particles of clay of some water, so small as to pass the sand or quartz, but they are caught by the feathery precipitate of alumina hydrate, much as the bacteria contained in air are prevented from entering a phial closed with sterilized wool."

So we see that, first, as in the case of the slow sand filter, so with the mechanical, bacterial removal efficiency does not so much depend upon the filtering material itself as upon an artificial surface or blanket being formed.

One of the most successful installations of mechanical filtration is that at Harrisburg, Pa. The average bacterial removal is above 99%, being 99.62% for the year 1908.

Now the assertion may be made that these methods of filtering water are not perfect. Efficiencies are given of something over 99%, but what about the remaining bacteria, the percentage number of which must depend upon the original number to start with. For instance there were days last year when the Harrisburg water presented as many as 85,250 bacteria colonies per c.c. Now a 99 per cent. removal would yet leave over 800 bacteria per c.c. in the water.

The answer to the above assertion is contained in the one word "sterilization." If a water is so impure from a pathogenic point of view that it requires to be filtered and it is necessary to guarantee it at all times then "disinfection", or "sterilization" as it is sometimes called, must form a final adjunct to any filtration process. This principle has been recognized for some time in Europe as illustrated by the number of ozone treatment plants which have been added to filtration plants. In many of the European rivers the bacterial counts run so high, that it is impossible to obtain by any method of filtration results which come anyway near the recognized standard for filtered water, viz, not more than 100 bacteria per c.c.

The principle is also being recognized in this continent. Nashville, Minneapolis, Quincy, New Jersey and many other towns, even including Harrisburg, have adopted methods of disinfecting the water, while in Canada we have several temporary plants installed in Toronto, Montreal, Pembroke and several in Western Canada.

Disinfection by ozone has not as yet found much favor in this continent, the disinfectant chiefly used being chlorine obtained from chloride of lime. With the Siemens, Halske & De. Fries system, efficient disinfecting results can be obtained with ozone. The process, however, of forcing contact between the ozone and the water is expensive, and even in cases as at St. Maur, Paris, costs more than the production of the gas. The difficulty arises owing to the fact that ozone is practically an insoluble gas in water, hence the difficulty of obtaining contact with every drop of water. In the case of chlorine in the form of hypochlorite we have a salt which is soluble in water, and which if properly mixed reaches every particle of water. The well known disinfecting action of chlorine depends upon its power of combining with the hydrogen of water and liberating the oxygen; thus $CL_2+H_2O=2\ HCL+O$.

This atom of oxygen is said to be nascent at the time of liberation and in this form acts as a most powerful disinfectant. The bleaching power of chloride of lime is due to the same reaction. As long as the lime is kept dry it has no bleaching action, but when in contact with moisture the reaction at once takes place.

The high disinfecting efficiencies obtained by mixing chlorine with water has, of late, brought it into great favor as a temporary expedient in cases of typhoid outbreaks due to impure water. The plant necessary for treatment can be fixed up practically in one day. The cost is a mere bagatelle, and the operating expenses run about 50 cents per 1,000,000 gallons of water treated.

The plant need not consist of any more elaborate detail than two or three 60 gallon casks with a small tank supplied with a ball cock to maintain a constant head fitted with a regulating tap at the orifice.

Hypochlorite is most economically and readily obtained from chloride of lime, the lime containing on the average about 33 per cent. of available chlorine. It is usual to mix in the barrels a one per cent. solution of the lime with water, viz., at the rate of 1 lb. of chloride of lime to 100 lbs. or 10 gallons of water. The lime settles out as calcium hydrate, and the liquid is led to the orifice tank from which it is dosed into the water supply in the necessary proportion.

The proportions of available chlorine to the amount of water requiring disinfection varies with the character of the water. Turbid water and water containing considerable amounts of vegetable matter require much more chlorine than waters which are practically free from these conditions. Ontario Lake water as normally represented by the quality at the intake is efficiently disinfected by the addition of .33 parts of available chlorine to 1,000,000 parts of water. Some waters require not more than .15, while others will practically eat up chlorine before it has any chance to act as a germicide. The reason for this variation is the affinity of organic matter to oxygen. No hard and fast rule can, therefore, be laid down for its application. Where a water may vary in condition. relative to turbidity and organic content, so the amount of chlorine must also be varied. The application is not dependent upon any hard and fast rule, but must be based upon a scientific knowledge of degrees of cause and effect.

A water which can be most efficiently treated with any disinfectant which relies upon nascent oxygen, should present constant conditions. If these constant conditions are not peculiar to a raw water, then they should be assured by some preliminary treatment before the disinfectant is applied. The preliminary treatment may take the form of sedimentation, slow sand filtration, mechanical filtration, or a combination of sedimentation and filtration, depending upon local conditions. This practically means that in the majority of cases disinfection is not likely to supersede the accepted general methods of purifying water, but that it will merely form an adjunct or final process, by which any water can be absolutely guaranteed as free from disease germs.

The introduction of disinfecting processes will probably in the future tend to a more favorable acceptance of rapid filter methods rather than slow methods. The main reason as we have seen, for a preference for slow sand filtration as against mechanical filtration, has existed in the higher efficiency of the former as a germ remover. Our newer knowledge that water of a constant character, as turned out by a mechanical filter, can be sterilized at a small cost, has caused many of the advocates of slow sand filtration to reconsider their former conclusions.

The question has been asked, whether the addition of hypochlorite deleteriously affects water for purposes of domestic use. The answer is, that the small amounts of chlorine required, do not in any way affect the water. Where it might be necessary to use large amounts of chlorine, the water must of a necessity receive preliminary treatment to allow of only reasonable amounts being used. The author is of opinion that our present knowledge of the subject limits the permissible amount of chlorine to about .50 parts in 1,000,000.

At the above rate of application it would require with chloride of lime containing 33 per cent. of available chlorine, as follows:

1.5 lbs. of chloride of lime to 1,000,000 lbs. of water.
=1.5 lbs. of chloride of lime to 100,000 gals. of water.
=15 lbs. of chloride of lime to 1,000,000 gals. of water.

In order to make a 1 per cent. solution sufficient for 1,000,000 gallons of water, it would require the 15 lbs. of chloride of lime to be mixed with 1500 lbs. of water, or 15 lbs. of lime to 150 gallons of water.

There is no doubt that disinfecting processes of water treatment have come to stay, just what form their exact relation will take up relative to older methods being yet somewhat undecided. However, I have as far as possible endeavored to lay before you the present situation relative to purification of water as far as the removal of pathogenity is concerned. Time will not allow of entering into the hundred and one other impurities which it may at times be necessary to treat. We have algae growths, vegetable iron growths, such as ferrigmous slime, spongidae, all kinds of complications caused by inorganic matters in solution, all of which are interesting and capable of remedy.

Sufficient is it, if I have shown you that waters, which at one time would have remained condemned as possible sources of water supply, may now be brought into general use.

MERCURY ARC RECTIFIERS.

H. A. COOCH, B.A.Sc.

The mercury arc rectifier was first introduced to meet the demand for some device for rectifying from alternating to direct current, economically, efficiently, and without occupying too much space in the power station. It is the case in a great many stations and substations at present that only alternating current machines are in use. As a result, it would necessitate a great outlay to install direct current machinery to supply d.c. needs. In such cases it is apparent that this arc rectifier is to play an important part in the betterment of local substation economics.

The first to realize the rectifying properties and possibilities of mercury was Mr. Peter Cooper-Hewitt, of the Cooper-Hewitt Mercury Arc Lamp Co., now absorbed by the Westinghouse interests. In his investigations he realized that mercury was of such a nature as to permit of rectification from a.c. to d.c. In April 1900, he perfected his first rectifier, the patents for which were secured in Jan. 1902.

At present there are some half dozen methods of obtaining direct from alternating current, all of which have disadvantages connected with them. Many of these disadvantages practically disappear, however, in the case of the mercury rectifier.

In the first place the motor-generator set is quite frequently used for the a.c. to d.c. transformation. This however is high in first cost and requires large floor space for installation. The efficiency at full load of sets of proper size for charging vehicle batteries has been comparatively low, and at light loads very low. In the case of high voltage d.c. for constant current series arc lights it would be impossible to obtain proper commutation on the d.c. machine, hence the operation of a number of series lights from a motor-generator set is an impossibility.

The single phase rotary converter is another method of rectification. However, it is not as flexible as the motor-generator set, particularly as regards voltage, and it requires more care and higher intelligence in starting and operating it. Besides, as in the case of the motor-generator set, we cannot commutate a sufficiently high d.c. voltage to maintain a set of series arc lamps.

Together with the above two most important methods we have a number of others which have proved more or less unsatisfactory under certain conditions. These include The Synchronous or Mechanically Driven Rectifier, sometimes called the Lethuele Rectifier, the Chemical Rectifier, in which aluminum is the important substance, due to its peculiar polar resistance; and Switching Devices for Rectification. There are also various forms of Electrolytic Rectifiers involving substances such as tantalum, carborundum, etc.

There are two distinct types of mercury rectifier, namely, low tension and high tension types. The storage battery charging outfit is a typical example of the first form where the pressures run below 300 volts.

The low tension set consists essentially of:

(a) An auto-transformer for excitation.
(b) A direct current reactance.
(c) The rectifier bulb and holder.
(d) An operative panel.
(e) A regulating reactance.

The auto-transformer, or compensator reactance, as it is sometimes called, is simply used to step the line voltage up or down a sufficient amount to give the desired terminal a.c. volts across the bulb. It consists in principle of two coils of an equal number of turns connected in series with one another, the middle point being connected through the d.c. load to the cathode. This is shown in Fig. 1.

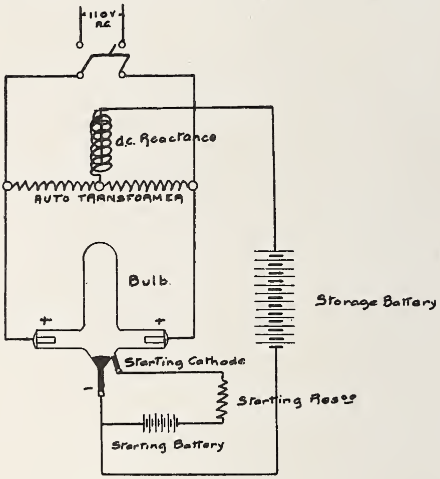


Fig 1

CONNECTIONS FOR LOW TENSION APPARATUS

In order to smooth out the otherwise rapidly fluctuating waves and also to cause the instantaneous current in one anode or cathode circuit to overlap the instantaneous current in the other by a small angle usually about 20°, we have sometimes a d.c. reactance in series with the d.c. load.

The Bulb and Holder.

The bulb or tube is a glass vessel exhausted to a high degree and sealed at the tip, the vacuum being necessary for the unimpeded flow of current. It is equipped with two anodes, one cathode, and one starting anode. The cathode and starting anode are filled with mercury. The production of the conducting vapor takes place at the surface of the cathode from what is known as the cathode spot. This cathode spot or bubble continually wanders around on the surface of the mercury cathode.

The size and shape of the bulb depends almost entirely on its capacity in amperes and volts, since it can be easily seen that higher voltage types require more protection against spatterings of mercury, and the consequent injurious effects from this cause, than the low voltage types; while the cross sectional area depends on the current required.

The rectifier bulb is supported at the back of the board by a holder consisting of a metal frame so pivoted at its centre that it can be rocked back and forth. The life of the bulb under normal operating conditions is at least 400 hours unless defective in manufacture. In fact the life of the bulb is almost a matter of guesswork unless perhaps it refuses to operate at all. Tests so far have shown an average of

3000 hours for the 10 ampere tubes.
2500 hours for the 20 ampere tubes.
700 hours for the 30 ampere tubes.

On the operating panel are mounted usually voltmeter, ammeter, double throw switches for connection to the supply and load circuit, and the necessary double pole and single pole switches for starting and operating the rectifier. Fuses and circuit breakers are provided for protecting the bulb against overloads. A starting resistance is mounted on one of the pipe supports and is connected in multiple with the pilot lamp mounted on the front of the board. The pilot lamp is used to indicate that the rectifier is in operation, and also acts as a warning that the starting resistance switch should be opened as the load is thrown on, as the lamp is dark when the rectifier is operating on the load only. The necessary reactance dials are also provided. The connections behind the panel can be seen in Fig. 2.

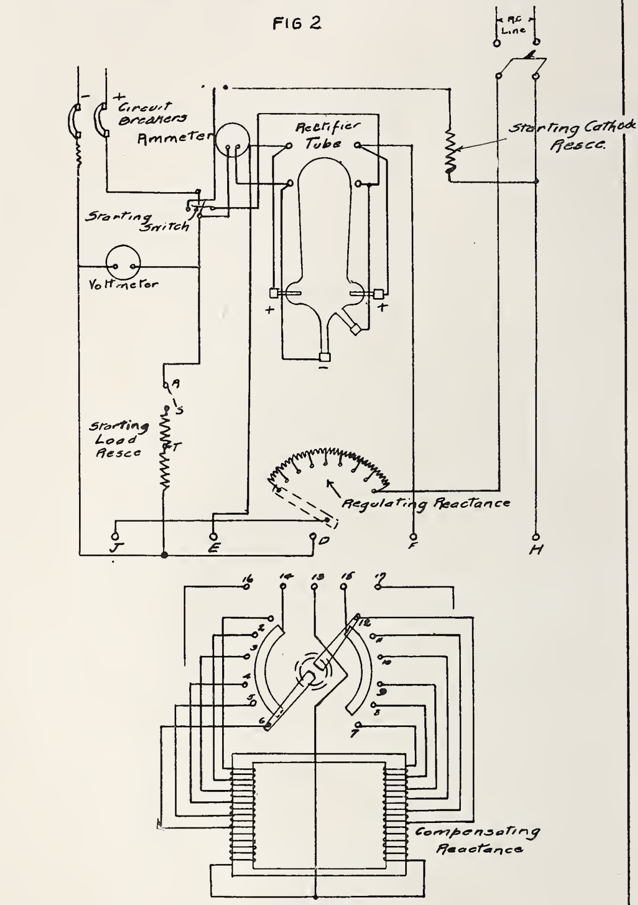
A smoother or finer control of d.c. voltage as well as current is obtained by a regulating device in series with the a.c. supply line and mounted on the pipe support back of the panel. It consists of a coil wound on a laminated iron core, a number of taps are taken from this coil and connected to a semi-dial switch mounted on the panel.

The high tension series arc lighting type consists of the following apparatus:

1. A constant current transformer.

CONNECTIONS OF SINGLE PHASE MERCURY RECT. PANEL

FIG 2



Connect J to 16; E to 14; D to 13; F to 15; H to 17

110 V ac Line Voltage	For 15 to 30 volts dc Connect	16 to 1; 17 to 7, A to T
	For 30 to 46 " "	16 " 6, 17 " 12, A " S
110 V ac – 220 V Line Voltage	Use 110 V ac " 30 - 45 " "	16 " 6; 17 " 12; A to T
	Use 220 V ac " 40 " 75 " "	16 " 1; 17 " 7, A to S
220 V ac Line Voltage	For 45 " 75 " "	16 " 1, 17 " 7, A to T
	" 75 " 115 " "	16 " 6; 17 12; A " S
330 V ac Line Voltage	" 90 - 120 " "	16 " 1; 17 " 7; A " T
	" 120 " 175 " "	16 " 6, 17 " 12, A " S

2. A d.c. reactance.
3. An exciting transformer for starting.
4. The rectifier bulb.

The transformer is of the usual constant current type, consisting of a three-legged laminated magnetic core, the middle leg of which is surrounded by two flat secondary coils fixed in position, and by a primary coil suspended on a rocker arm.

The d.c. reactance is tapped off the neutral of the transformer secondaries which acts the same as in the case of the storage battery charging apparatus, to store up and give out energy and hence to smooth out the waves. The exciting transformer consists merely of a step-down transformer exciting the primary. The secondary terminals are connected to the cathode and starting anodes.

The high tension bulb is similar to those described previously although, being of high voltage, it must necessarily have better protection for its anodes. The entire apparatus in an assembled form for arc lighting service is shown in Fig. 3.

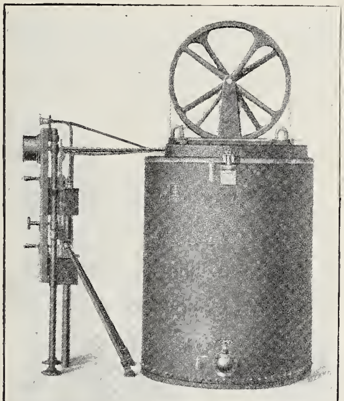


Fig. 3.

The large tank in the cut is filled with transformer oil and not only provides for a cooling effect on the bulb and other portions of the apparatus but also acts as a high tension insulator. About 90° F. is the best temperature for operation, the lower limit being about 50° F.

The action or principle of operation of the mercury rectifier is a subject upon which experts seem to vary a great deal. In fact three distinct theories are developed for its action, namely, the Steinmetz arc theory, the Thomas cathode resistance theory, and the Wagoner ionization theory. Of these three the Wagoner theory seems to be the easiest to follow. It maintains that the action of the rectifier tube is based on the production of negatively charged ions at the cathode spot. These ions can be deprived of their negative charges only at a positive electrode. Since there exists in the tube no means of producing negative ions at the anodes, for the very reason that there happens to be no mercury at the anodes, the current passes in one direction only in the arc stream. The unidirectional passage of current is not a property of the mercury vapor (which under ordinary circumstances is not a conductor at all), but is the result of the employment of ion producing cathodes and anodes, which do not produce negative ions, but merely relieve such ions of their charges. Should an ion producing spot, or cathode be established accidentally on either anode, current would pass or arcing would take place from one anode to the other as already described, causing a short circuit of the tube. The flow of current in the rectifier can best be discussed with reference to Fig. 4. Assume an instant when the terminal H of the supply transformer is positive. Then the anode A is positive and the arc is free to flow between A & B. Following the direction of the arrows still further the current passes through the load J, through the reactance coil E, and back to the negative terminal on the transformer, G. A little later, when the impressed E. M. F. falls below a sufficient value to maintain the arc against the counter E. M. F. of the arc and load, the reactance E which has hitherto been charging, now discharges, the discharge current being in the same direction as formerly. This serves to maintain the arc in the rectifier until the E. M. F. of the

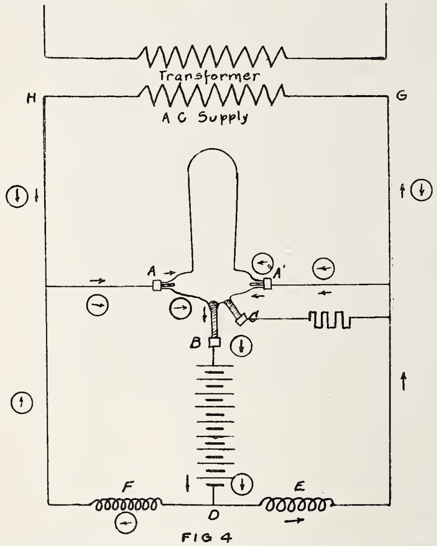


FIG 4

DIAGRAM REPRESENTING FLOW OF CURRENTS IN RECTIFIER
(Wagoner Theory)

supply has passed through zero, reverses, and builds up to such a value as to cause A^1 to have a sufficiently positive value to start an arc between it and the mercury cathode B.

The discharge circuit of the reactance coil E is now through the arc A^1 B instead of through the former circuit. Consequently the arc A^1 B is now supplied with current, partly from the transformer and partly from the coil E. The new circuit from the transformer is indicated by arrows enclosed in circles.

Methods of Starting.

There are several methods for starting the rectifier, or for causing the evaporation of the mercury. The common one is that of starting a spark to jump by breaking contact between the mercury in the starting anode and the cathode by shaking the tube and thus giving consequent vaporization. Or, the above is sometimes performed automatically by magnetic coils. A third in use is the aluminum starting method—where a coating of aluminum on the outside of the cathode is connected through a condenser to the anode, causing the mercury and glass at the cathode to be of opposite polarity; hence causing sparking with resultant vaporization.

Frequency and Power-Factor.

The frequencies possible on the mercury arc rectifier are really those which it is possible to apply to the transformer. However, standard outfits will operate satisfactorily on any frequency from 25 to 140 cycles, although they are usually designed for 60 cycles. The variation in frequency would, of course, depend on the other apparatus including transformers, reactance, etc. The power-factor of the system is about .9, depending on the amount of reactance in and out of the circuits.

Efficiency.

To illustrate the economical efficiency of the battery charging rectifier over the motor-generator set, let us consider an example. Suppose each to be charging a 44 cell battery, the operation being performed in accordance with conditions of time and current recommended by the manufacturer. The first part of the charge is to be at 28 amperes and 106 volts (average) for 5 hours. The efficiency of the motor-generator set at this load is 62%, and of the rectifier set at the same load, 80%.

The second part of the charge is at 12 amperes, and 108 volts (average) for two hours. In this case the efficiency of the former set is 36%, and of the rectifier 81%.

In the motor-generator set the first part of the charge requires 23.93 K. W. hours and the second part 7.2 K. W. hours from the service mains, or a total of 31.13 K. W. hours during the charge. Considering power to cost 6 cents per K. W. hour, the cost per charge amounts to $1.867.

In the case of the rectifier, the first section of the charge requires 18 K. W. hours, and the second part 3.2 K. W. hours from the service mains, making a total of 21.7 K. W. hours. At 6 cents, the cost per charge is $1.302. This shows a saving of 56½ cents per charge by using the rectifier.

Assuming the minimum life of the bulb to be 400 hours, an average of seven hours per charge allows the bulb to experience 57 charges. During this time the total saving amounts to $32.20.

Of late, rectifiers have been applied to numerous uses besides those of battery charging and constant current series arc lighting. Among them are the following: railway signals and car lighting, telegraph systems, fire and police alarm systems; motor-boats, hotel annunciators; chemical laboratory and electrolytic work, electroplating; surfacing and casting machines, elevator purposes, etc.

The many advantages of the apparatus, such as simplicity of operation, economy of initial cost, high efficiency of conversion, long life of rectifier bulbs, and fine gradations of current adjustment throughout the full range, are increased by absence of moving machinery, small space to be occupied, etc.

The outlook for the rectifier is brilliant. Its advancement has surprised even the most optimistic manufacturers. Should its construction in the future be so imposed as to allow of high commercial currents, it will undoubtedly become a central station necessity.

WATER WHEEL GOVERNORS.

E. R. FROST, B.A.Sc.

The ideal turbine governor would be one that would effect a change in output by varying only the quantity of water supplied to the wheel, thus obtaining perfect water economy by conserving unneeded water for future use. This is not possible in practice, as head water, and therefore efficiency, are usually wasted when operating a wheel under other than its normal load.

The success of the comparatively recent application of hydraulic power to the operation of alternators in parallel, and to the generation of current for electric lighting, street railway and synchronous motor loads has been largely dependent upon the possibility of obtaining close speed regulation with good water economy and without undue shock upon machinery and penstocks, while working under extremely varying loads.

While the development of automatic governing apparatus has been almost entirely experimental, remarkable results have been attained, so that some of the modern turbine governors under favorable conditions operate quite as well as modern steam engine governors.

If we consider for a moment the problem of governing a turbine we shall see that it is not at all so simple a matter as would at first appear.

The conditions of the installation have a marked effect on the difficulties to be overcome in turbine governing. If the wheel is set in an open flume having only a short draft tube, so that the water flows to the gates from every direction, the velocity of flow from any direction is very low. The quantity of water which moves at a high velocity is confined to the wheel and draft tube, and a change in the velocity and momentum due to a change in the gates produces no serious effects.

If, however, the water be brought to the wheel in a long penstock, and leaves in a long draft tube, the conditions become quite different. A large amount of energy is stored up in the moving column of water, and if an attempt is made at too rapid regulation the wheel will be left deficient in energy when more power is desired, or when the power is decreased, may produce shocks that will seriously affect the regulation or may cause serious damage to the penstock and wheel.

If the load on the wheel is decreased, the velocity of the water in the penstock must be decreased, and vice versa; work must be done on the water to accelerate it, and must be absorbed to retard it. The work required to accelerate the water must be obtained at the expense of the work done upon the wheel. Thus, when a load is thrown on the unit and the governor opens the gates, the immediate effect is a decrease in the output of the wheel, even below its original value, which is just opposite to the effect desired. Unless energy in some form is available to partially supply this deficiency, the speed of the wheel will fall considerably before readjustment to normal conditions can take place.

In the same way energy must be absorbed when the load is decreased. If this is expended on the wheel the speed will rise above normal. It may be partly dissipated by such means as relief valves or standpipes.

The water in the draft tube must also be accelerated or retarded at each change of gate at the expense of power output in exactly the same way as that in the penstock.

Since the immediate effect of the gate motion is the opposite to that intended, the governor to work properly must be made to anticipate the amount the gate must be moved to bring the speed back to normal. It must move just this far, or a little farther, and then stop and wait for the speed to return to normal.

The governor which does this is said to be "dead beat," or is compensated. Most governors of the later types, as will be shown later, are so constructed that adjustments may be made to give the degree of compensation desired. The speed of the ordinary wheel is away from normal two or three seconds, and since the best large hydraulic governors can make a full stroke in two seconds or less, it will be seen that unless the governor were compensated the gate would be entirely opened or closed long before the speed were back to normal, with the result that the wheel would race.

The different makes of governors are distinguished by their different mechanisms for compensating, and some of them have been brought to such perfection that to see one of them operating, one would almost think the machine provided with brains.

Before taking up the construction of governors it might be well to look into some of the conditions effecting regulation.

Water Hammer.—"If the closure of the gates is rapid, the column of water in the penstock is set into vibrations or oscillations, which in a long pipe under high heads is very dangerous to the wheel and penstock. If the partial gate closure is slow enough each increment in pressure is gradually dissipated along the pipe, and the hammer is avoided.

The extinction of a velocity of four feet per second at a uniform rate in one second in a pipe 1,600 feet long would create a pressure head of about 200 feet, or a total longitudinal thrust on the pipe line at each bend and upon the wheel gate of 24 inches in diameter of about 20 tons.

Hence it is seen that gate movements must be sufficiently slow to avoid dangerous oscillatory waves. This has to be decided for each plant depending on the conditions existing.

To take care of sudden pressure, relief valves and standpipes are often used.

In cases where the head is not very great, say up to 80 or 100 feet, stand-pipes are generally best, as they are certain of operating, and do not waste water. A stand-pipe is simply a large pipe built upright from the main penstock as close to the wheels as possible. It is open at the top, so that the water may rise and fall in it with the variation in pressure in the penstock. A stand-pipe answers two purposes: (1) As a relief valve, and (2) as a storage of energy to take care of sudden increases of load while the water is accelerating and to dissipate the excess kinetic energy in the moving column of water at a time of sudden drop in the load. For these purposes it should be as near the wheel as possible, and of ample diameter.

When the head gets over 100 feet it is impracticable to build stand-pipes owing to the cost of building a structure high enough and strong enough to withstand the wind pressure, and also because the inertia of the long column of water in the standpipe will give rise to strains as injurious as those they are designed to relieve.

A relief valve is arranged to open when the pressure rises above a set value and allow water to waste into the draft tube or other convenient place. An ordinary valve, such as that used for steam, would open and close so rapidly as to act like a reed upon an organ pipe, and thus maintain and increase the vibration of the mass. In order to be at all effective the valve must be dead beat. Though it must open quickly, it must close very slowly. Relief valves are now made, generally of the hydraulic type, which will open instantly and take several minutes to close, the speed of action being, of course, adjustable. Although means have thus been found for relieving the penstock of excessively high pressures, no means have yet been found for quickly accelerating the water when because of an increase in load the speed begins to fall. As already explained, when the governor opens the gates, the inertia of the mass cannot keep pace with the increased demand for water, with the result that the pressure drops, and the speed of the wheel will drop still farther. This may continue for several seconds till the water column has become sufficiently accelerated to supply the needs of the wheel.

If the governor is not made very dead beat the gates by this time will be open too wide, with the result that the speed will go too high, causing the governor to close the gates quickly, so that the relief valves will operate, which, of course, will result in very poor speed regulation.

If the governor is made dead beat enough to avoid pressure oscillation the speed regulation will be poor if the load changes are large and sudden. It is impossible for this to be otherwise, because the column of water cannot possibly alter the energy given to the wheel fast enough, whether the gates be in one position or another.

The only complete remedy for the troubles in speed regulation caused by excessive inertia of a water column is some form of by-pass valve directly connected with the water wheel gates and arranged to open when they close, and thus keep the velocity of the water nearly constant.

This would be equivalent to an impulse wheel arranged with a deflecting nozzle. It would, of course, be very wasteful of water, and in most installations could not be used.

A modification of this principle is used at Turbine, Ontario. In this case the valve, or by-pass, is indirectly controlled by the movement of the governor. The gate-controlling rack which is moved by the governor piston is extended by a piston rod having a piston on its end placed in a cylinder filled with oil. From either end of this cylinder pipes are taken to a controlling piston which operates the relief valve exhausting water from the wheel case into the draft tube. Hence any movement of the governor piston will affect the relief valve. When the governor closes quickly the valve will open, and a movement in the opposite direction will close it. As it is not desirable to have the relief valve open for small movements of the gates the cylinder is provided with an adjustable by-pass so that unless the governor makes a sudden movement of some length the oil will pass from one end of the cylinder to the other.

The small cylinder operating the valve is also provided with a by-pass so that the pressure is gradually reduced, allowing the valve to close. It was found when using this arrangement that the valve had a tendency to stay open too much, owing partly to the pressure of the water on the face of the valve. A large spring was then put behind it to insure of its closing. The by-pass, of course, regulates the speed of closing.

Governors.—To pass on now to a description of a few types of governors:

In all reaction turbines, and in all impulse turbines, with the exception of tangential wheels, the governor controls the speed by opening or closing the regulating gates, thus varying the amount of water supplied to the wheel.

As a large force is necessary to move the gates (sometimes 50,000 pounds), it is clear that they cannot be moved by fly balls alone, as in the case of a steam engine. Consequently some form of relay mechanism has to be used. That is, the movement of the balls controls some independent power for moving the gates. There are two classes of governors, viz., mechanical and hydraulic, each being classified by the type of its relay mechanism. In the mechanical type the power to move the gates is supplied by the wheel itself by means of belts, friction clutches, gears, etc. The fly balls throw into action pawls, friction gears, or other mechanical devices which will bring the relay into action. When the relay is of the hydraulic type it generally consists of a piston connected by some mechanical device to the gate rigging and moved by means of the hydraulic pressure of the water taken from the penstock or other source or by oil supplied under high pressure from a reservoir, usually the latter.

The pressure of the oil in the reservoir is kept up by pumps driven either from the wheel itself or by a separate motor. The oil used in moving the piston is exhausted into a receiver and pumped back into the supply reservoir. The relay is usually controlled by the ball governor, through the medium of a small valve, which by its motion admits the oil or water directly to the main piston or else to a secondary piston which controls a larger admission valve.

The mechanical governor is cheaper to build, and probably requires less attention than the hydraulic type, but on the other hand, it takes power from the wheel just at the time when more power is needed. It is also slower, and in the case of some wheels whose gates have a tendency to close themselves, a constant rubbing of the friction wheels is necessary to keep them open. Where the wheels operate factory machinery or machinery of that class, the mechanical governor is generally quite satisfactory and also cheaper to install.

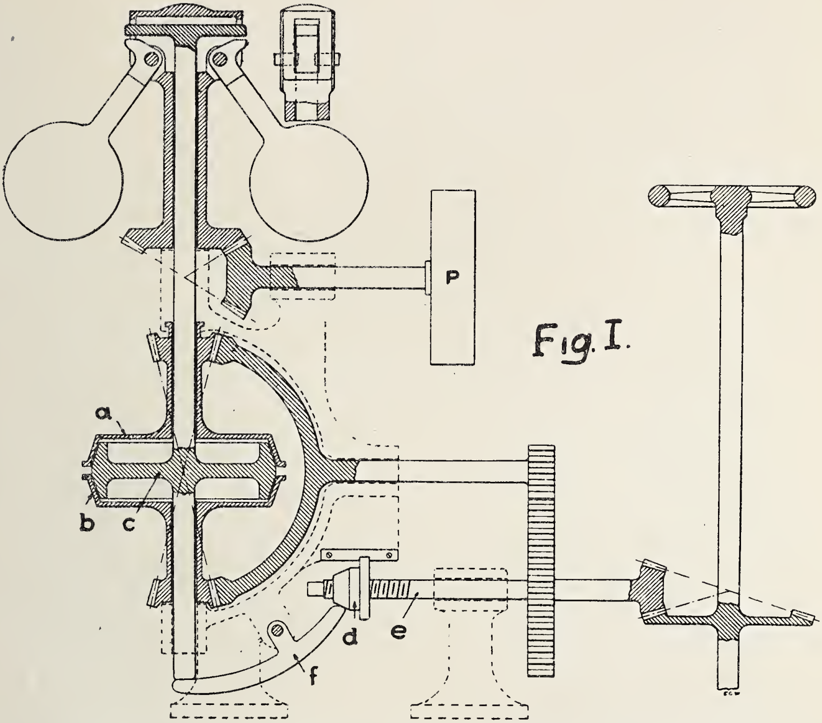


Fig. 284.—Diagramatic Section of Woodward Simple Mechanical Governor,

Fig. I shows a simple form of mechanical governor, made by the Woodward Governor Co., Rockford, Illinois.

On the upright shaft are two friction pans (a and b). These pans are loose on the shaft, the upper one being supported in position by a groove in the hub, and the lower one by an adjustable step bearing. Between these pans, and bevelled to fit them, is a double-faced friction wheel (c) which is keyed to the shaft. This shaft and friction wheel run continuously, and have a slight endwise movement. They are supported by lugs on the ball arm, and therefore rise and fall as the position of the balls varies with the speed.

When the speed is normal, the inner, or friction wheel, revolves freely between the two outer wheels or pans, which remain stationary. When a change of speed occurs the friction wheel is brought against the upper or lower pan as the speed is either slow or fast. This causes the latter to revolve, and by means of the bevel gearings, turns the gates in the proper direction until the speed is again normal. As the gate opens, the nut (d) travels along the screw (e) which is driven through gearing by the main governor shaft, and as the gate reacts, the nut (d) coming in contact with the lever (f) throws the vertical shaft upward and the governor out of commission. This governor is not dead beat, but where load changes are not very rapid or frequent, the governor works quite satisfactorily, and requires almost no attention. It may be used to advantage on exciters in small plants and for light work. The Woodward Co. also make a compensating governor of the mechanical type, but as space is limited, it will be necessary to show only one of each class.

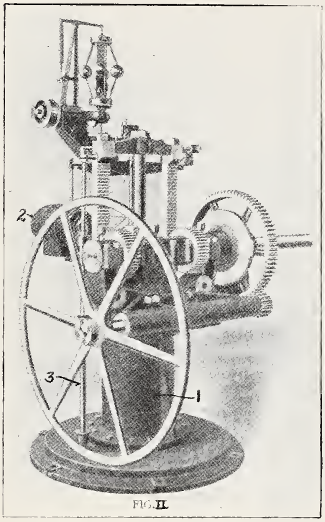


FIG. II

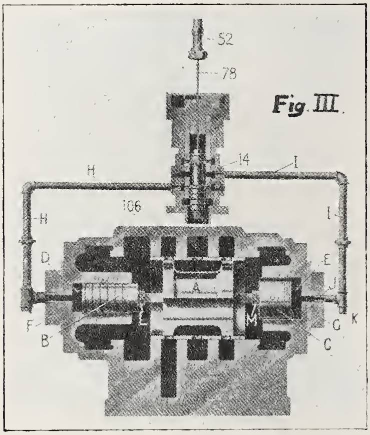


Fig. III.

Fig. 2 shows the Lombard Governor Co.'s Type N governor. It will be seen that the main working cylinder (1) is vertical, and that the movement of the piston up or down is transmitted through the double rack and pinions to the operating shaft. The balls control a small regulating valve, 14, Fig. 3, which admits oil from the pressure tank to the relay valve, 2. At 3 is seen the displacement cylinder with its piston connected rigidly to the rack bars.

Fig. 3 is a section of the relay valve, 2. Its method of operation is as follows:

A is the relay valve, which may be moved in either direction by the plungers B and C. Since the plunger B has one-half area of plunger C, the latter can overpower the former if the pressures in the cylinders E and D are equal. Cylinder D is connected through pipe H to the pressure supply; hence the tendency of B is always to move valve H towards the valve head G. Oil is exhausted or supplied through the pipe I. K leads to the displacement cylinder, while H is connected with the pressure tank. When valve 14 is moved by balls in one direction it admits oil from pressure tank to I, forcing A to left, which admits oil to lower side of main piston, and opens the upper side to the exhaust. The main piston rises, moving the wheel gates. In moving up, the displacement piston is carried up, creating a partial vacuum in the displacement cylinder. This draws part of the oil from I through K, and as the piston moves farther, all the oil in I is exhausted, with the result the valve, A, stops. The main piston, however, continues to move as long as valve 14 is open. When this is closed A is closed, because the liquid in cylinder, E, escapes to the displacement cylinder. When A is closed the governor comes to rest.

When 14 is moved in the opposite direction the opposite to the above takes place, so that A moves to the right till the valve, 14, takes a new position. It will be seen that any movement of the regulating valve, 14, is duplicated by the main piston, and that when valve 14 is again in its neutral position, A is immediately closed.

The anti-racing mechanism is not seen in the cut, but is arranged as follows:

The stem of valve 14 is threaded into the head of the fly balls so that any rotary motion given to it will raise or lower it. Any motion of the main piston is transmitted through a reducing motion and dash pot to a small rack engaging with a gear on the stem of valve 14.

When the speed of the wheel gets away from normal, regulating valve 14 is displaced, causing main piston to move. The reducing motion working through the dash pot and rack turns the valve stem so that the valve is closed, bringing the governor to rest to wait for the speed to return to normal. By adjusting the by-pass of the dash pot the governor may be compensated to any degree to suit the particular conditions of the installation. That is, the governor will move the gates just far enough to bring the speed back to normal, and will stop there. The Sturgess hydraulic governor uses an expansive pulley to drive the governor balls. When the main piston moves it carries with it a cam, which through a dash pot actuates a lever, expanding or contracting the pulley, thus bringing the balls back to normal speed before the wheel is actually up to normal speed.

In the case of impulse wheels, which are generally used with very high heads and long penstocks, it is impracticable to build penstocks which are strong enough to withstand the shocks due to sudden closures of gates, hence a deflecting nozzle is used. That is, the nozzle is hinged, and when it is desired to decrease the output, the nozzle is deflected from the blades. If the needle valve is set to carry peak loads there will be a waste of water at all other loads. This condition is commonly improved somewhat by adjusting the needle valve about once an hour, by means of a slow motion hand wheel, for the maximum load liable to occur during that period. An automatic governor has lately been invented, which adjusts the needle valve slowly automatically, so that the stream is kept on the blades. This is done by the use of an electric motor, a connection being made which starts the motor as soon as the nozzle deflects. The motor is geared to move the valve slowly. In large installations employing hydraulic governors it is generally the custom now to have one set of pumps and pressure system to supply all the governors in place of having a separate pump and tanks for each governor. This has the advantage that only one pump and pressure system have to be kept up, but on the other hand, should this pump fail, all governors are out of commission. This is generally overcome by having a duplicate pressure stystem to take the place of the working system while repairs are made or while the first system is being cleaned out. The different companies making governors supply special oil, but they do not seem to have yet found an oil which will stand up under the continued surging around the system. A substance like cement forms in the bottom of the tanks and piping which is very difficult to remove. Some good work might be done in experimenting along this line.

REPORT OF DUTY TRIAL ON THE SIX MILLION IMPERIAL GALLON PUMPING ENGINE AT THE HIGH LEVEL PUMPING STATION, TORONTO WATER WORKS.

ROBERT W. ANGUS, B.A.Sc.
Professor of Mechanical Engineering.

The city of Toronto has two pumping stations for the supply of water to the city proper, exclusive of that supplied to the residents of Toronto Island. Of these two the main pumping station is situated at the foot of John St., close to the bay, and all the water supplied to the city passes through pumps in this station, the pressure being maintained at slightly over 90 pds. per sq. in.

As the ground rises very rapidly as one proceeds northward from the bay, the pressure in the northern part of the city produced by the pumps at the main pumping station, would be rather low and in the district near the Canadian Pacific Railway does not much exceed 21 pds. per sq. in.

In order to maintain the proper pressure in the northern part of the city the High Level Pumping Station was built on Poplar Plains Road a short distance above the Canadian Pacific Railway tracks.

The growth of the northern part of the city has been very rapid of late years and the consequent consumption of water

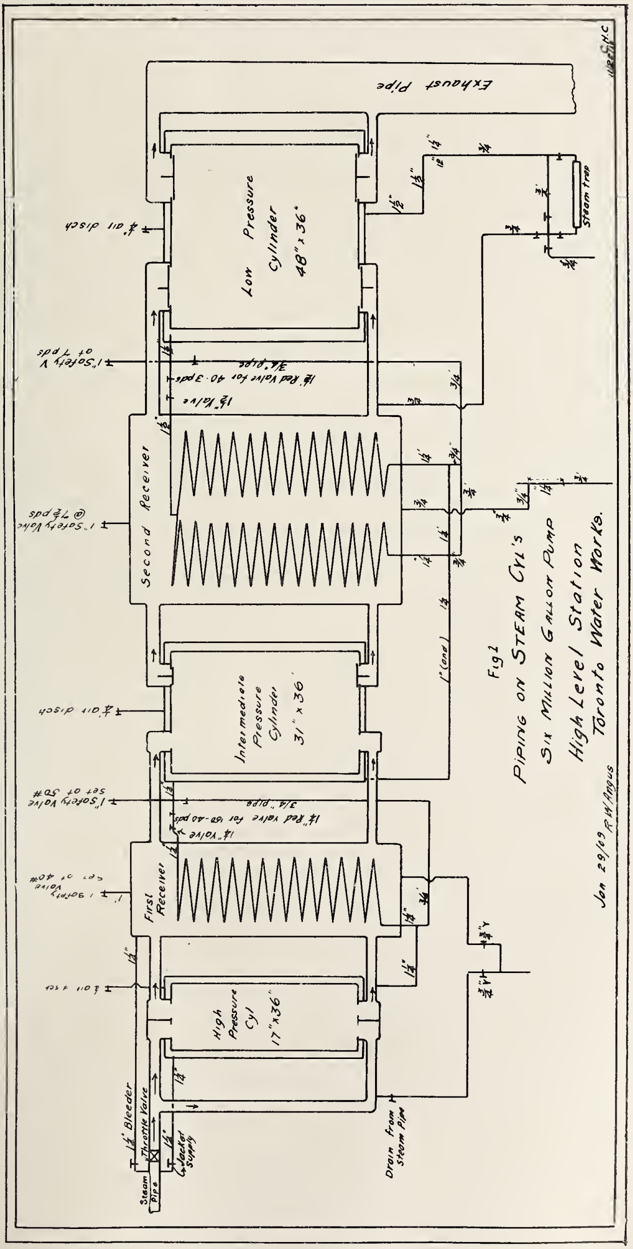


Fig 1

Piping on Steam Cyl's
Six Million Gallon Pump
High Level Station
Toronto Water Works.

Jan 29/09 R.W. Angus

has so increased that the pumps originally installed in the station were unable to maintain a sufficiently high pressure, so that an additional pump, having a capacity of six million Imperial gallons per day against a pressure of 75 pds. per sq. in., has been installed and it is this latter pump with which this report deals.

Description of the Engine.

The engine tested is a three-cylinder, vertical, triple-expansion crank and fly-wheel pump having three single acting plungers direct-connected to the pistons of the three steam cylinders. It is designed to give a discharge of six million Imperial gallons per twenty-four hours against a discharge pressure of 75 pds. per sq. in. for domestic purposes but is also capable of giving the same discharge against a pressure of 100 pds. per sq. in. for fire purposes.

The nominal diameters of the steam cylinders as given on the working drawings, are 17 in., 31¼ in., and 48 in., respecttively and the nominal diameter of all water plungers is 21¾ in., the stroke for all plungers and pistons being 36 in. For the duty trial the diameters and strokes of the water plungers were determined with great care, as is explained later, but the dimensions of the steam cylinders were not verified.

To the crosshead of the low-pressure plunger are attached the feed pump, the air pump, and an air compressor for providing compressed air in the discharge air chambers and also for the operation of the steam cylinder poppet valves if desired.

The engine has three cranks placed 120 degrees apart, the sequence being high pressure, low pressure and intermediate pressure. The crank shaft is made in two parts, which are joined together at the central crank by a sliding block which gives the shaft some flexibility without affecting its working.

Steam cylinders and piping.—A diagram of the steam piping for the engine is given at Fig. 1, which shows the main steam piping as well as that for the jackets and reheaters. Each of the cylinders is provided with a steam jacket and receivers are placed between each pair of cylinders, a reheating coil being placed in each of the receivers. The sizes and arrangement of pipes are shown on the drawing and are as follows:

(a) *Cylinder-Steam piping.*—After passing the throttle valve the steam main has two five-inch branches one of which carries steam to the top of the high pressure cylinder, the other to the bottom of the same cylinder. The exhaust from the high pressure cylinder is conveyed by two pipes, each 5 in. diameter, to the first receiver where it is reheated before being delivered to the intermediate cylinder through two pipes each 8½ in. diameter.

From the intermediate cylinder the steam passes through two pipes into the second receiver where it is again reheated before being sent to the low-pressure cylinder. After passing through the latter cylinder the steam is conveyed by the 16 in. exhaust pipe to the heater and finally to the condenser.

(b) *Jacket and reheater piping.*—The jacket supply is drawn from the main steam pipe on the boiler side of the throttle valve by means of a 1¼ in. pipe, which pipe contains a valve and connects directly with the high pressure jacket.

On leaving the high-pressure jacket the steam passes, by means of a 1¼ in. pipe, to the reheating coil in the first receiver, from which it is conveyed through a 1¼ in. pipe containing a 1¼ in. globe valve and a 1¼ in. reducing valve, (set for reducing the pressure from 150 pds. to 40 pds.), to the intermediate jacket. This 1¼ in. pipe also contains a 1 in. safety valve set at 50 pds.

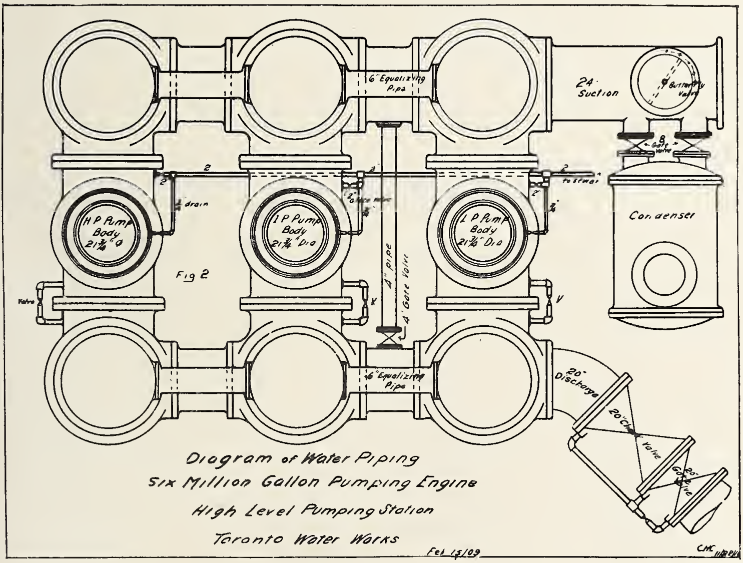


Fig 2

Diagram of Water Piping
Six Million Gallon Pumping Engine
High Level Pumping Station
Toronto Water Works

After passing through the intermediate jacket the steam passes through a 1 in. pipe which is enlarged to 1¼ in. into the two reheating coils in the second receiver, which coils are arranged in parallel. The steam leaves these coils through a single 1½ in. pipe, on which is a globe valve, a 1½ in. reducing valve set for reducing the pressure from 40 pds. to 3 pds., and a safety valve set at 7 pds. This 1½ in. pipe delivers the steam into the low pressure jacket.

On leaving this jacket a 1½ in. pipe, which is reduced to 1¼ in. and finally to ¾ in. delivers the steam to a trap from which it passes by a ¾ in. pipe to the sewer.

For drainage from the jackets and receivers and the reheating coil ¾ in. pipes are arranged as shown.

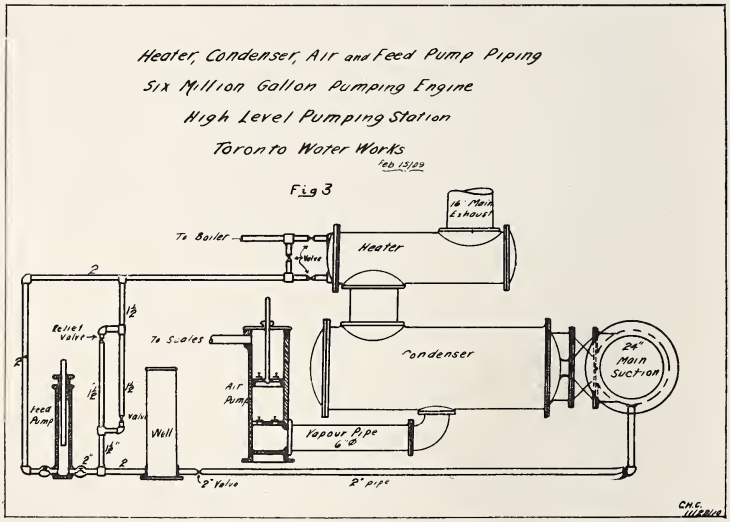
(c) *Other piping.*—A 1¼ in. pipe is connected from the main steam pipe on the boiler side of the throttle to the first receiver for starting up. This pipe contains a 1¼ in. globe valve.

Air discharge pipes each ¼ in. diameter and supplied with a valve are placed at the top of each cylinder jacket.

A 1 in. safety valve set at 40 pds. is placed on the first receiver and a similar valve set at 7½ pds. on the second receiver.

The high pressure cylinder has Corliss admission and exhaust valves, and on the intermediate cylinder Corliss admission valves are used, while for the exhaust for this cylinder and the admission and exhaust for the low pressure cylinder poppet valves are used.

The speed of the engine is controlled by a flyball governor which operates on the high-pressure valves only and in case the speed becomes excessive this governor also opens a valve in the condenser so as to admit air to the latter and "break" the vacuum.



Feed Water and Condenser Piping.

The feed water and condenser piping scheme is shown on Figs. 2 and 3.

The cooling water for the condenser is taken from and again returned to the suction pipe of the engine. A butterfly valve is placed in the main 24 in. suction pipe and the cooling water is drawn from this pipe, on the side of the butterfly valve remote from the pump, through an 8 in. valve and pipe passing into the condenser. After passing through the condenser the water is returned to the suction main through an 8 in. pipe and valve but on the side of the butterfly closest to the engine. By the proper adjustment of the butterfly valve any desired proportion of the water may be sent through the condenser.

The area of the butterfly valve is about 80% of the area of the 24 in. pipe but it is never set at less than 22½° to the normal to the pipe axis and when fully open is turned parallel to the pipe axis in which case it offers practically no resistance to flow and very little water would pass through the condenser.

The exhaust steam first passes through a feed water heater and then on to the condenser. After being condensed the steam passes through a 6 in. pipe to the air pump from which it is discharged to the sewer.

The feed water is drawn from the main suction pipe through a 2 in. pipe, containing a valve, into the well. From the well a 2 in. pipe delivers the water to the feed pump from which it is discharged through a 2 in. pipe. As shown on the drawings the water may be sent through the heater or not as desired. A by-pass of 1½ in. pipe and containing valves is connected from the suction to the discharge pipe of the feed pump.

Main Water Piping.

The water enters the pumphouse through a 24 in. pipe containing a gate valve close to the wall of the room. It then passes down the south side of the engine supplying water to the suction air chambers. After passing through the pump cylinders the water is discharged at the north side of the pump through a 20 in. pipe containing a check valve and a gate valve.

A 4 in. by-pass pipe with valve may be used to connect the suction and discharge sides of the pump if desired. This pipe is placed between the intermediate and low pressure parts of the engine.

Equalizer pipes, 10 in. diameter, connect the three suction air chambers and similar pipes connect the discharge air chambers. Air is forced into the discharge air chambers by means of the air compressor attached to the low-pressure crosshead.

The remainder of the piping consists of a 2 in. pipe with valve connected to the plunger chamber and free to discharge into the sewer provided the valve is open. The valve is controlled by a wheel on the engine room main floor. There is also a 2 in. by-pass from the plunger chamber to the discharge chamber of each pump. This pipe also contains a valve which may be opened by a hand wheel on the main floor.

Pumps.

The pumps are single-acting, and corresponding to each plunger there is one suction and one discharge chamber. The valves are arranged in cages, there being for each plunger seven valve cages, each cage containing 25 valves. There are thus 525 suction valves and 525 discharge valves.

The area through each of the valves is given on the drawings as 5.95 sq. in., but this was not verified.

NOMINAL DIMENSIONS OF ENGINE AND PUMPS.

Note:—The dimensions given in the following table are all taken from the working drawings but were not verified, as they are not essential to the duty trial. The exact diameter and stroke of each plunger is given elsewhere, but the sizes given on the drawings are set down here for convenience.

1. Nominal Dimensions of the Engine.

High Pressure Cylinder:—

Diameter of piston	in.	17
Diameter of counterbore of cylinder	in.	17⅛
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

Intermediate Pressure Cylinder:—

Diameter of piston	in.	31¼
Diameter of counterbore of cylinder	in.	31 5-16
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

Low Pressure Cylinder:—

Diameter of piston	in.	48
Diameter of counterbore of cylinder	in.	48⅛
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

First Reheating Receiver:—

Diameter of two steam pipes entering	in.	5
Diameter of two steam pipes leaving	in.	8½
Volume of receiver	cu. ft.	33.5
Size pipe in reheating coil (o.d. copper tubing)	in.	1¼
Number of coils		1
Number of turns per coil		18
Mean diameter of coil	in.	24
Heating surface in coil	sq. ft.	37

Second Reheating Receiver:—

Diameter of two steam pipes entering	in.	8½
Volume of receiver	cu. ft.	47

Size of pipe in reheating coils (o.d. copper tubing)	in.	1¼
Number of coils		2
Number of turns per coil		22
Mean diameter of coils	in.	28
Heating surface in two coils	sq. ft.	64

Condenser:—

Diameter of shell inside	in.	36¼
Diameter of exhaust inlet	in.	16
Diameter of condensed steam outlet	in.	6
Diameter of water conections	in.	8
Tubes No. 16 B. W. G., outside diam.	in.	1
Length of tubes between plates	ft.	5
Number of tubes		228
Cooling surface in condenser	sq. ft.	300

Feed water Heater:—

Diameter of shell inside	in.	16
Length between tube plates	in.	58
Diameter of steam inlet and outlet	in.	16
Diameter of water connections	in.	2
Tubes No. 18 gauge, outside diam	in.	⅝
Length of tubes between plates	in.	58
Number of tubes		68

Air and Feed Pumps:—

Air Pump—Single Acting.

Diameter	in.	12
Stroke	in.	36
Diameter of inlet pipe	in.	6
Diameter of discharge pipe	in.	8

Feed Pump—Single Acting.

Diameter	in.	1¾
Stroke	in.	36
Diameter of inlet pipe	in.	2
Diameter of outlet pipe	in.	2

Air Compressor:—

Diameter	in.	3
Stroke	in.	36
Water jacket pipes, inlet and outlet	in.	¾

General Dimensions:—

Length of connecting rod, centre to centre	ft.	7½
Diameter of crank shafts in fly wheel	in.	12½
Diameter of main bearings	in.	10½
Length of main bearings	in.	18
Diameter of hole through shaft	in.	3
Crank pins—diameter	in.	6½

Crank pins—length	in.	6
Crosshead pins—diameter	in.	6½
Crosshead pins—length	in.	6
Diameter of steam pipe	in.	
Diameter of exhaust pipe	in.	16
Number of flywheels		2
Diameter of wheels	ft.	12 1-3
Rim 11in. and 12 in. wide, 12 in. thick.		
Length of hub	in.	17½
Weight of each wheel	lbs.	20000

2. Nominal Dimensions of the Pumps.

Diameter of plungers	in.	21¾
Stroke of plungers	in.	36

Valves:—

Rubber, arranged on sides and top of cages, secured to deck plates.

Number of valve deck plates		6
Number of holes for cages in each plate		7
Total number of valve cages		42
Number of valves per cage		25
Total valves in entire pump		1050
Water opening in each valve	sq. in.	5.95

(Note—one-half (525) of the above valves are suction, the rest discharge).

Air Chambers:—

Number of suction air chambers	3
Number of discharge air chambers	3

Piping:—

Suction pipe diameter	in.	24
Discharge pipe diameter	in.	20
Equalizer pipes, diameter	in.	10
Number of distance rods to plungers		12
Diameter of each rod	in.	3

The Duty Trial.

According to the specifications and contract, "The engine shall perform a duty of not less than one hundred and sixty million (160,000,000) foot pounds for each one thousand (1000) pounds of commercially dry steam used by the engine and any auxiliary pumps supplied by the contractor and operated during the duty trial. Steam containing less than 1½ per cent. of entrained water, as determined by calorimeter measurements, shall be considered as commercially dry steam. In computing the duty, the work performed by the engine shall be based upon plunger displacement. The head for computing the duty shall be that shown by an accurate pressure gauge attached to the discharge main at a point inside of the engine room and beyond the last pump, less the reading shown by a gauge attached to the supply main at or near the entrance to pump. No allowance shall be made for friction of water in pumps or pipes between the pump well and the gauge attached to the discharge main. In computing the duty, the total steam used, including that used by jackets, reheaters, and auxiliary pumps, shall be charged to the engine. The duty trial shall be of twenty-four hours' duration. The engine shall be operated continuously at the rated capacity against a head equal to 75 pds. pressure per sq. in. on the discharge main, and shall be supplied with steam of not more than 150 pds. pressure per sq. in., by gauge, at the boiler."

"The engine shall have a capacity of six million Imperial gallons in twenty-four (24) hours when operated at a plunger speed of not over 180 ft. per min., against a head equal to 75 pds. pressure per sq. in., on the pumps."

It is further stated in the general data given the contractor that the pressure in the suction main is 15 pds. per sq. in.

The trial was made as closely as possible under the contract conditions; as however, the pressure in the suction main, on account of some alterations in the city water piping system, had been raised to about 25 pds. per sq. in., the pressure on the discharge main during the test was about 85 pds. per sq. in., in order to obtain the pressure difference of 60 pds. per sq. in. between suction and discharge mains contemplated in the contract.

Weight of Steam Used.

The steam chargeable to the engine was determined by the condensation from the condenser, the jackets, the reheater, etc., and tanks were arranged, placed on scales, so that the weight of the condensed steam could be directly determined. The condensation from the condenser was measured by itself in one set of tanks, and that from the jackets and other drain pipes in a second and smaller set. The weights of condensed steam were measured every half hour, two observers checking all weights independently, setting down their results and comparing them before making the entry on the observation sheet.

Pressure.

The pressure on the discharge main was taken by an accurately calibrated Bourdon gauge, the piping leading to which was attached outside the last connecting branch from the pump. The pressure on the suction main was measured similarly by an accurately calibrated Bourdon gauge, the attachment being made close to where the suction main enters the pumping station, just outside of the condenser. The gauges themselves were placed side by side in a position where they could be conveniently read from the engine platform, about fourteen feet above the suction and discharge mains, correction being made for water column. The pressure difference was maintained as closely as possible at 60 pds. by manipulating a gate valve on the discharge main placed outside the point of attachment of the discharge gauge. During the night the pressure on the discharge main became excessive, and in order to maintain the pressure difference at the required figure it was found necessary to open a hydrant adjacent to the station.

The steam pressure at the engine was determined by an accurately calibrated Bourdon gauge, and the pressure in the calorimeter by a mercury manometer.

The pressures in the first and second receivers were taken from gauges on the gauge board. These gauges were not calibrated, but correction was made for water column. The vacuum in the exhaust pipe was taken from the vacuum gauges at the gauge board which was not calibrated.

The pressure in the steam jackets was determined from the regular gauges attached to the jacket, which were not calibrated or corrected in any way.

The barometer reading was obtained from the Observatory at intervals during the test. The result given is the average throughout the 24 hours, corrected to the height of the High Level Pumping Station, and the temperature of the engine room.

Speed.

The speed of the engine was determined by the revolution counter attached to the gauge board, the reading on this counter being checked by a second counter specially set up for the test; the counters agreed perfectly.

The Quality of the Steam.

The quality of the steam was determined by a throttling calorimeter connected to the steam main on the engine side of the throttle valve. The calorimeter worked satisfactorily throughout the test. The percentage of moisture in the steam was low, and showed very little variation throughout. The steam used by the calorimeter was not weighed.

Temperatures.

The temperatures of the engine room and of the boiler room were observed throughout the test.

The temperature of the exhaust was obtained from a thermometer placed in the exhaust pipe about eight feet below where the latter left the engine.

Indicator Diagrams.

Indicator diagrams of the steam and pump cylinders were taken at intervals during the test.

Measurements of the Plunger.

The diameters of the plungers were measured Wednesday, April 7th, the engine being shut down at about 4 p.m. for this purpose. By means of a steel tape, measurements of the circumference of each plunger at each end and at the middle were made. The plunger on the high pressure end was found to taper slightly from the bottom to the top, being largest at the bottom. In computing the diameters and areas of the plungers from this tape measurement, corrections were introduced for temperature, and for thickness of the tape, the tape itself being compared with a Government Standard.

The average diameter of each plunger determined as indicated above was used in computing the plunger displacement.

The strokes of the plungers were measured after the trial. A strip of oak 1½ inches square on which were fastened brackets and adjusting screws was firmly fixed between points on the frame and made parallel with the piston rod. A stout pointer, with a flattened end, the thickness of which was accurately measured, was then firmly clamped to one of the distance rods connecting the pump plunger to the cross head of the engine. The bracket screws were then so adjusted that the lower one just touched the under surface of the flattened pointer at the bottom of the stroke, and the upper one its upper surface at the top of the stroke. The distance between the points of the adjusting screws, less the thickness of the pointer end gave the length of the stroke. In determining the distance between the points of the screws a special bar was used whose length had been ascertained by micrometer callipers.

Calibration of Apparatus.

The steam gauges on the boiler and on the steam supply to the calorimeter, and the water gauges on the suction and discharge mains were calibrated both before and after the test by means of a Crosby gauge tester, and the results of the calibration were applied to the gauge readings in computing the results of the test; the readings were also corrected for water column, where necessary.

The jacket gauges, the first and second receiver gauges and the vacuum gauges, being those supplied by the contractor and fastened in place on the gauge board or other portion of the engine, were not calibrated, as extreme accuracy in their readings was not essential for purpose of the test; the recorded readings of these gauges have, however, been corrected for water column where necessary.

The thermometers used were not calibrated.

The scales used in measuring the weight of condensed steam were tested by the government inspector of weights and measures both before and after the trial.

The smaller scales on which the condensation from the jackets, reheaters, etc., were found to be accurate within the range of the weights measured; the larger scales on which the condensation from the condenser was weighed were found to average one pound light within the range of weights measured. A correction for this has been made.

Observations.

With the exception of the measurement of the condensed steams, which readings, as mentioned above, were taken every half hour, and the barometer and thermometer readings, the observations were made every ten minutes.

Weather Conditions.

The weather on the afternoon of Thursday, April 8th, was sunny and warm, for the time of year, but during the night it became much colder, and there was some slight fall of snow. Friday was somewhat cold and damp.

Starting the Trial.

The trial began at 2.30 p.m. Thursday, April 8th, and ended at 2.30 p.m. Friday, April 9th, 1909. The watch used in the trial was compared with a chronometer at the beginning and end of the test, and was found to have lost approximately two seconds in the twenty-four hours.

The engine, after having been stopped for the plunger measurement on the previous evening, had been in operation for at least eight hours previous to the commencement of the trial, and was thoroughly warmed up. It ran satisfactorily throughout, with the exception of a slight vibration, caused by some of the cams operating and the valves on the low pressure cylinder not working quite smoothly.

The poppet valves on the intermediate and low pressure cylinders are arranged to be closed by springs or by air pressure; during the test the spring closure was used, the air compressor being used simply to keep air in the air chambers of the pumps.

Towards the end of the test a small leakage of steam from the high pressure cylinder jacket developed owing to a slight failure of the packing; the drip was caught, and from it the total loss due to this leak estimated. The weight was added to the total weight of water measured on the scales.

Observers.

The observers worked in eight-hour shifts, but each shift was present for about ten hours. These men were all skilled in such work, being students in the fourth year of the Faculty of Applied Science and Engineering of Toronto University.

The trial was under the direction of Professor Robert W. Angus, and was carried out by Mr. M. R. Riddell, in conjunction with Mr. W. W. Gray and Mr. J. J. Traill, all of the Faculty of Applied Science of the University of Toronto.

All calculations from the original observation sheets were made by Mr. Riddell. These calculations have been thoroughly checked.

Mr. Hill watched the test in the interest of the contractors.

The engineers and firemen at the pumping station were under the direction and control of the station engineer.

Measurements of the Pumps Used in Computations.

High-pressure Plunger—

Stroke, actual	inches,	35.947
Diameter, actual		21.751
Displacement per revolution	cubic feet	7.730

Intermediate-pressure Plunger

Stroke, actual	inches	36.007
Diameter, actual		21.757
Displacement per revolution	cubic feet	7.747

Low-pressure Plunger—

Stroke, actual	inches	35.972
Diameter, actual		21.760
Displacement per revolution	cubic feet	7.742
Total displacement per revolution	cubic feet	23.219
Total displacement per revolution	imp. gals.	144.699
Volume of imperial gallon	cubic inches	277.274

Observations and Results.

Date of Trial—

2.30 p.m. Thursday, April 8th, to 2.30 p.m. Friday, April 9th.

Duration of Trial—24 hours..

Corrected Average Pressures—

Boiler pressure by gauge, pounds per sq. inch	150.21
At engine pressure by gauge, pounds per sq. inch	148.85
In first receiver by gauge, pounds per sq. inch	24.04
In second receiver by gauge, pounds per sq. inch (below atmosphere)	4.09
In intermediate jacket by gauge, pounds per sq. inch	39.08
In low pressure jacket by gauge, pounds per sq. inch	1.17
Vacuum by gauge, ins. mercury	27.39
Pressure on discharge main, pounds per sq. inch	85.14
Pressure on suction main, pounds per sq. inch	25.16
Height of centre line of discharge main above centre line of suction main at point of gauge attachment feet	0.7
Corresponding pressure, pounds per sq. inch	0.30
Total pressure, difference on pumps, pounds per sq. inch	60.28

Barometer, average, at pump floor level and temperature, ins. mercury	29.54
Average Temperatures—	
Of engine room, degrees Fahr. (lower platform)	76
Of boiler room, degrees Fahr.	66
Of exhaust steam, deg. Fahr.	105.5
Calorimeter—	
Pressure of supply steam at calorimeter, pounds per sq. inch	148.85
Pressure of steam in calorimeter (1 in. mercury =.4908 pounds per sq. inch)	1.21
Temperature in calorimeter, degrees Fahr.	298
Moisture in steam, per cent.	0.72
Speeds—	
Total number of revolutions by counter	43,185
Average revolutions per minute	29.99
Average plunger speed, feet per minute	179.814
Water Pumped—	
Total number of revolutions	43,185
Plunger displacement per revolution, cubic feet	23.219
Plunger displacement per revolution, imp. gals.	144.699
Displacement in twenty-four hours, imp. gals	6,248,813
Work Done—	
Total number of revolutions	43,185
Displacement per revolution, cubic feet	23.219
Total pressure difference on pumps, pounds per sq. inch	60.28
Work done per revolution, ft. pounds	201,542
Work done in twenty-four hours, ft. pounds,	8,703,603,033
Steam Used by Engine—	
Total condensation from condenser, pounds	45,091
Total condensation from jackets, receivers, etc., lbs.	8,072
Total steam used by engine, pounds	53,163
Duty—	
Work done by pump in twenty-four hours, ft. pounds	8,703,603,033
Steam used by engine in twenty-four hours, lbs.	53,163
Duty per thousand pounds of steam used, ft. lbs.	163,715,423
Duty required by specifications, ft lbs.	160,000,000

POWER FACTOR CORRECTION.

L. S. ODELL, '09.

In these days A. C. power systems are becoming so common, and the attendant problems in power factor correction, so well understood, that to those familiar with the subject, any further discussion of power factor correction by the use of the synchronous motor must seem superfluous. However, the general installation of these power systems in Western Ontario has to some extent revived interest in an old subject, as is manifested by the enquiries received by manufacturers of electrical apparatus regarding the synchronous motor, its adaptability to the correction of power factor on systems already installed and the size and design of the motor required. It is in the hope that this discussion may be of some service in answering these enquiries that the same is published.

Whenever power is used from an A.C. line, whether it be through the medium of synchronous or induction motors or by means of a transformer, as is the case for lighting purposes, it is always found that the reading of the wattmeter, showing the power used, is less than the product of volts and amperes on the line. The percentage that the former is of the latter is the power factor. The energy component of the power carried by a line is the volt amperes x power factor. We have also to consider a wattless power component displaced 90 degrees in phase from the energy component, so that $P.F.^2 + W.F.^2 = 1$ where W.F. is the factor, by which we multiply the volt amperes to give the wattless power component. In a power system these wattless power components are not registered on the customer's meter, nor do they directly necessitate any increase in power at the generating station. However, a low power factor on a system means that a current much greater than that required for real power consumption is being carried, necessitating greater line capacity, larger machines, etc., and increasing the losses due to inductance, capacity losses, friction, etc. On a light load these losses may become very large, compared with the load, giving a system of very low efficiency.

Induction motors, when working, cause a lagging current. Transformers also constitute an inductive load, and create a lagging wattless component of power, but when used in connection with a lamp load, the reduction of power factor is not so serious. Now the wattless component of a synchronous motor, under certain conditions, leads the power component, so it is at once evident that synchronous and induction motors might be worked together on a system in such a way as to make the leading and lagging effects neutralize and create a power factor of practically unity.

Induction motors are the more common type in use for general purpose work, so that usually a synchronous motor, when it is put in, is employed to correct a loss power factor due to lagging currents caused by the former type of motors. Suppose this power factor is .8. Experiment shows that as the power factor is corrected more and more nearly to unity, the capacity of the synchronous motor required to make a further change becomes relatively much greater as, for example, if a motor of 100 K.V.A. capacity were required to correct the power factor from .8 to .95, one of 200 K.V.A. capacity would probably be required to bring it up to unity. Hence it is not consistent with economy in first cost to install a motor large enough to completely correct the power factor of a system, as the last few per cent. of correction are dearly paid for in the increased K.V.A. capacity required in the motor. The better practice is to install a motor large enough to bring the power factor to .90 or .95 when the system is fully loaded, while on light loads the capacity of the motor will be sufficient to raise the P.F. still higher, and perhaps completely correct it.

The synchronous motor will do its work as a corrector of the power factor whether coupled to an external mechanical load or not. However, it is advisable to put it on such an external load if possible. Such a load will be represented in the motor by a power component in quadrature with the current used for power factor correction, giving a resultant load not much in excess of the correction load even with a considerable mechanical output. For example, in one case it was found that an external load, equal to 50 per cent. of the correction load could be carried with an increase in the required K.V.A. capacity of the motor of only 12 per cent.

The following example will serve to further illustrate the circumstances under which a synchronous motor may be installed. Suppose induction motors are now carrying a load of 800 K.W., with a power factor of .8. It is desired to determine the capacity of a motor of the former type which will correct the power factor to .95 and carry a load of 200 K.W.

Wattless current due to induction motor load at .8 power factor, $\sqrt{1-.8^2}\times{}^1/_{.8}\times 800=600$ K.V.A.

Total wattless current due to load of 1,000 K.W. at .95 power factor$=\sqrt{1-.95^2}\times{}^1/_{.95}\times 1{,}000=336$ K.V.A.

Hence the synchronous motor must furnish the difference between these two results, the former being the initial lagging component and the latter the lagging component after correction. Combining this difference of 264 K.V.A. with the mechanical load of 200 K.V.A. in quadrature we have:

$\sqrt{264^2+200^2}=332$ K.V.A.=total capacity of the synchronous motor.

Then the power factor at which the synchronous motor will operate as $\frac{200}{332}$ = .6 approximately.

Hence in above case a synchronous motor of 332 K.V.A. capacity must be installed, and the excitation so controlled that it will operate under a power factor of .6.

The reason for this adjustment of excitation is as follows: Such a motor when operating under any particular impressed voltage, sustains a constant magnetic flux, no matter what the exciting current may be. A lagging or leading induced armature current is set up, this induced current being such as, when combined with the field excitation, will give a constant magnetizing force. When the fields are over excited a leading current will flow in the armature, and hence a synchronous motor must always be over excited when used to correct a power factor which is held down by lagging currents. When operating a synchronous motor, as explained above an increase in the field excitation will increase the leading current it will draw from the line, while decreasing the field excitation will decrease this leading current until when this leading current falls to zero the motor is operating under unity power factor. A further decrease in excitation would cause the machine to draw a lagging current from the line, so that if necessary a synchronous motor could be used to correct power factors for either leading or lagging currents.

Certain important characteristics effect the suitability of a motor for this class of work. Any AC generator would operate as a synchronous motor, but used for correction of power factors held down by lagging currents, might not be satisfactory. These machines are over excited, and the excitation increases directly as the current, while the heating effects in the field coils increase as the square of the current. Hence machines of low frequency where the number of poles is small and which often give trouble by heating when used as generators, will not do at all, owing to the high temperature in the fields. A machine with a small air gap decreases the amount of excitation necessary. Also the weaker the armature, or in other words, the fewer the coils in it, and the lower the resistance of those coils, the greater will be the induced leading current for the same increase in field excitation. Hence the characteristics of a good machine for power factor correction are a large number of low resistance fields, a small air gap and a weak armature. Such a machine, however, is not likely to be satisfactory as a generator.

Throughout the country there are a great many induction motors operating on power factors of from .5 to .7, and in many cases power consumers are being penalized by the companies, who insist on a power factor of .9 to secure the lowest rates. The synchronous motor offers a means of correction of this difficulty. In many cases, however, the saving will not justify the expense entailed, especially where there is the employment of skilled labor to be reckoned on along with the installation. In other cases, where the load is taken off at only a short distance from the generator, the initial expense is again prohibitive, as the increased generator capacity is the only saving effected. However, on long transmission lines where a low power factor necessitates increased capacity of generators, step up and step down transformers and all other apparatus in the system there is no question as to the advisability of using some means to balance up the lagging and leading currents and hold the power factor as near unity as possible.

THE ENGINEERING SOCIETY

The November sectional meetings of the society were held on Wednesday, the 16th. J. W. Nelson, B.A. Sc., addressed the civil section on "Surveying the Alaska Boundary." His paper was well illustrated by a series of 150 slides, and being well acquainted with his subject, he said a great deal to relieve the impression that the country was an uninteresting one. "Water Wheel Governors," by E. R. Frost, B.A. Sc., was the subject at the mechanical and electrical meeting. The paper appears in full elsewhere in this number of "Applied Science." The miners and chemists were favored with an address on "Common Food Stuffs; Their Manufacture and Adulteration," by L. J. Rogers, B.A. Sc. All the meetings were well attended.

On Wednesday, Nov. 9th, the men of the third year journeyed to the Lackawanna Steel Plant, Buffalo, under the direction of Mr. T. R. Loudon and Mr. J. A. Stiles. In parties of ten and twelve, they were guided through the works, and given an excellent chance of seeing the various processes, from the unloading of the ore at the docks, to the loading of the finished product for shipment. The entire series of processes covers a period of about fifteen hours, and requires the services of some 7,000 men.

Another beneficial excursion, this one under the supervision of Mr. Murphy, vice-president of the civil section, was that to Centre Island, where the new filtration plant is in the course of construction. Mr. Longley, the engineer in charge, spared no pains in guiding and instructing the men as to what is being accomplished there. He not only went into the details of the plant, but also explained many of the outside aqueous problems.

NOTICE.

The graduates in and around Toronto should keep in mind a special meeting of the Engineering Society on Monday evening, Dec. 12th. Mr. Isham Randolph, of Chicago, is to give an illustrated address on the "Ship and Sanitary Canal of Chicago." To hear Mr. Randolph, one of the foremost consulting engineers in America, is an opportunity open to all who can possibly attend.

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STRESSES IN CIRCULAR RINGS WITH INTERNAL WATER PRESSURE.

T. H. Hogg, B.A. Sc.

The subject of this paper is the development of the stresses set up in a circular ring under internal water pressure.

The development of the theory is along similar lines to the work of C. W. Filkins and E. J. Fort, who developed the stresses in circular rings due to the weight of the rings themselves, and whose work is published in the "Transactions of the Association of Civil Engineers of Cornell University" for 1896. A reference to similar work is also made in a paper by Mr. Muller in the "Engineering Record" for May 1st, 1909.

The results contained in this paper were arrived at while the writer was working under the direction of Mr. R. D. Johnson of Niagara Falls. It is suggested that Mr. Johnson's article on the Hydrostatic Cord, which appeared in the April 1st, 1910, issue of the Canadian Engineer be read in connection with this paper; as the work contained herein is a development of some of the formulae used by him.

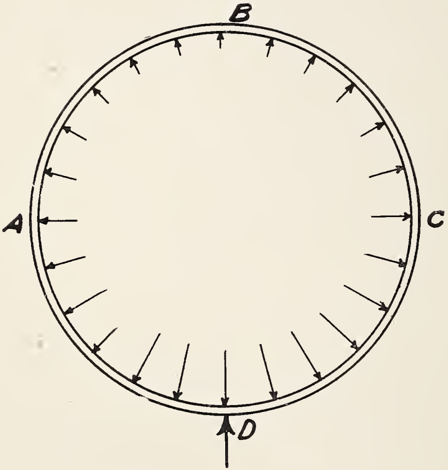
It is usually assumed in figuring the stresses due to internal water pressure in circular rings or pipes, lying on their sides, that it is quite sufficient to take only the tension induced in the shell into account, and that the bending moment may be neglected. This is only true where the pressure head is great compared to the diameter of the pipe. It is easily seen that where this condition does not exist there is a much greater pressure at the bottom of the pipe than at the top, and this may cause relatively great bending moments in the shell.

In the following discussion, the ring is assumed supported on a knife edge, and water pressure is assumed level with the crown of the pipe. The analysis also assumes a thin ring of homogeneous material having a constant modulus of elasticity, and that the changes from a circular form will have little effect upon the dimensions of the ring.

The following nomenclature will be used throughout the discussion:—

H=head of water above top of pipe.

r=radius of circular pipe.
M=bending moment in pipe.
M_B=bending moment in pipe at top.
M_D=bending moment in pipe at bottom.
M_{max}=bending moment in pipe at maximum point on side.
T=tension in pipe.
T_B=tension in pipe at top.
T_D=tension in pipe at bottom.
ϕ=angle to different points (expressed in radians).
ϕ_{max}=angle to maximum bending moment point on side.
ϕ_u=angle to upper node point (point of no bending moment).
ϕ_l=angle to lower node point (point of no bending moment).
γ=weight of cu. ft. of water.
J=shear at any point.
J_B=shear at top.
J_D=shear at bottom.
$d\delta$=arm of bending moment.



Theoretic Support

FIG 1

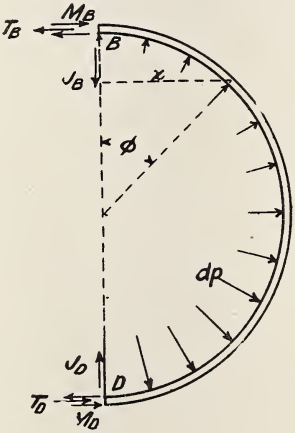


FIG. 2

We will assume that the reader is familiar with the three general formulae for arch-ribs.

$$\int_D^B \frac{Mds}{EI} = \int_D^B d\phi\ ; \int_D^B \frac{Myds}{EI} = \int_D^B dx\ ;$$

$$\int_B^B \frac{Mxds}{EI} = \int_D^B dy\ .$$

The ring is a continuous curved beam to which these equations will apply.

The forces acting upon the pipe may be appreciated by looking at Fig. 1. If we cut the pipe at *B* and *D* and consider the forces acting on the section to the right, we obtain the system of forces shown in Fig. 2.

Taking the centre of moments at the neutral axis at *D* we obtain:

$$M_D = M_B - 2\,T_B\,r + \int_0^\pi (1 - \cos\phi)\,d\,p\,\sin\phi$$

now

$$d\,p = \gamma\,r^2\,(1 - \cos\phi)\,d\,\phi\ ;\ \text{and}\ \sin\phi\,d\,p = \gamma r^2\,(1 - \cos)\ \sin\phi\,d\,\phi$$

Therefore

$$M_D = M_B - 2\,T_B\,r + \int_0^\pi \gamma\,r^3\,(1 - \cos\phi)\,\sin\phi\,d\,\phi$$

Integrating we obtain:

$$M_D = M_B - 2\,T_B\,r + 2\,\gamma\,r^3$$

Now consider as a free body that portion of pipe shown in Fig. 3.

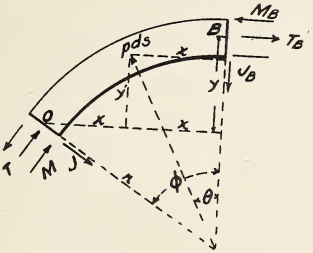


FIG 3

$$E\,I\,\Delta\,y = \int M\,x\,d\,s\ ;\ ds = r\,d\,\phi = r\,d\,\theta$$

$$-M = M_B - T_B\,y + \int_0^B p\,ds\,x$$

$$p\,ds = \gamma\,r^2\,(1 - \cos\theta)\,d\,\theta$$

$$x = r\sin(\phi - \theta)$$

$$y = r\,(1 - \cos\phi).$$

Therefore

$$-M = M_B - T_B\,r\,(1 - \cos\phi) + \int_0^\phi \gamma\,r^3\,(1 - \cos\theta)\ \sin(\phi - \theta)\,d\,\theta$$

$$= M_B - T_B\,r + T_B\,r\cos\phi + \gamma\,r^3 \int_0^\phi (1 - \cos\theta\ \sin(\phi - \theta)\,d\,\theta$$

$$= M_B - T_B\,r + T_B\,r\cos\phi + \gamma\,r^3\,(1 - \cos\phi - \tfrac{1}{2}\,\phi\sin\phi)$$

Therefore

$$E I \Delta y = \int M x \, d s = \int M r^2 \sin \phi \, d \phi$$

$$= -\int_0^\pi [\, (M_B r^2 - T_B r^3 + \gamma r^5) \sin \phi \, d\phi + (T_B r^3 - \gamma r^5) \sin \phi \cos \phi \, d\phi - \tfrac{1}{2} \gamma r^5 \phi \sin^2 \phi \, d \phi$$

Solving above equation we obtain:

$$E I \Delta y = -2 (M_B r^2 - T_B r^3 + \gamma r^5) + \frac{\gamma r^5 \pi^2}{8}$$

Also $E I \Delta x = \int_D^B M \, (ds) \, y = 0$ since B has not moved horizontally and since its tangent is horizontal.

Now $y = r \, (1 - \cos \phi)$; $d s = r \, d \phi$.

Therefore $E I \Delta x = r \int_0^{\pi r} M \, d s - r^2 \int_0^\pi M \cos \phi \, d \phi$

$$0 = r \int_0^{\pi r} M \, d s - r^2 \int_0^\pi M \cos \phi \, d \phi.$$

Substitute value of M found above and solve.

Therefore $-\int_0^\pi M \cos \phi \, d \phi = \int_0^\pi [(M_B - T_B r + \gamma r^3) \cos \phi \, d \phi + (T_B r - \gamma r^3) \cos^2 \phi \, u\phi - \tfrac{1}{2} \gamma r^3 \phi \sin \phi \cos \phi \, d \phi]$

Therefore $-\int_0^\pi M \cos \phi \, d\phi = \frac{\pi}{2} \left\{ T_B r - \gamma r^3 \right\} + \frac{\gamma r^3 \pi}{8}$

$$\text{or} \int_D^B M y \, ds = \frac{\pi r^3}{2} \left\{ T_B - \frac{3 \gamma r^2}{8} \right\} = 0$$

Therefore $T_B = \frac{3}{4} \gamma r^2$

Now $\int_C^B M \, d s = 0 = \int_0^\pi [M_B r \, d \phi - T_B r^2 (d \phi - \cos \phi \, d \phi) + \gamma r^4 (d \phi - \cos \phi \, d \phi - \frac{1}{2} \phi \sin \phi \, d \phi)]$

whence, solving above,

$$M_B = T_B r - \frac{1}{2} \gamma r^3$$

Therefore $M_B = \frac{\gamma r^3}{4}$

Now $M_D = M_B + 2 \gamma r^3 - 2 T_B r$

$$= \frac{\gamma r^3}{4} 2 \gamma r^3 - \frac{3 \gamma r^3}{2}$$

$$= \frac{3}{4} \gamma r^3$$

Now $-M = M_B - T_B\, r + T_B\, r \cos\phi + \gamma\, r^3 \left(1 - \cos\phi - \frac{1}{2}\,\phi \sin\phi\right) = \gamma\, r^3 \left(\frac{1}{2} - \frac{1}{4}\cos\phi - \frac{1}{2}\,\phi\sin\phi\right)$

which is the general expression for the bending moment.

To find the shortening of the vertical diameter substitute the values of M_B and T_B in the equation.

$$E\, I\, \Delta\, y = -2\,(M_B\, r^2 - T_B\, r^3 + \gamma\, r^5) + \frac{\gamma\, r^5\, \pi^2}{8}$$

We obtain: $E\, I\, \Delta\, y = -\gamma\, r^5 + \frac{\gamma\, r^3\, \pi^2}{8}$

$$\Delta\, y = \frac{\gamma\, r^5}{E I}\left(\frac{\pi^2}{8} - 1\right) = +\,.2337\,\frac{\gamma\, r^5}{E\, I}$$

To find the lengthening of horizonthal diameter

$$E\, I\, \Delta\, x = \int^{B} M\,(ds)\, y$$

Therefore

$$-E\, I\, \Delta\, x = \int_0^{\frac{\pi}{2}} \Big[\,(M_B - T_B\, r + \gamma\, r^3)\, r^2\,(1 - \cos\phi)\, d\,\phi + (T_B\, r - \gamma\, r^3)\, r^2\,(\cos\phi - \cos^2\phi)\, d\,\phi - \frac{1}{2}\,\gamma\, r^5\,(1 - \cos\phi)\,\phi\sin\phi\, d\,\phi$$

Solving $-E\, I\, \Delta\, x = \frac{\gamma\, r^5}{4}\,(1.5\,\pi - 5)$

$$= -\,.0719\,\gamma\, r^5$$

Therefore $\Delta\, x = .0719\,\frac{\gamma\, r^5}{E\, I}$

The whole change in horizontal diameter

$= 2\,\Delta\, x = .1438\,\frac{\gamma\, r^5}{E\, I}$

In order to find the value of ϕ where the moment is a maximum, place $\frac{d\,M}{d\,\phi} = O$

Therefore $T_B\, r\, d \cos\phi - \gamma\, r^3\, d\cos\phi - \frac{1}{2}\,\gamma\, r^3\, d\,\phi\sin\phi = O$

Differentiating and simplifying we obtain:

$$\phi \cot\phi = -\frac{1}{2}$$

$$-2\,\phi = \tan\phi$$

By trial we find $\phi = 105^\circ - 13' - 45''.4$; also $\phi = O$.

Now, when $\phi = O$ the maximum moment $M_B = \frac{\gamma\, r^3}{4}$

When $\phi = 105° — 13' — 45''.4$ substitute in exrpession for moment

$$-M = M_B - T\ r + T_B\, r \cos\phi + \gamma r^3 \left(1 - \cos\phi - \frac{1}{2}\phi \sin\phi\right)$$

and we obtain $M = -.3203\, \gamma r^3$

Assembling and comparing the values of the moments found we see that $M_B = + \frac{\gamma r^3}{4}$; $M_D = + \frac{3\gamma r^3}{4}$

and $M_{Max} = -.3203\, \gamma r^3$

Therefore, we see that the moment of the stress couple changes sign (i.e., passes through zero) between M_B and M_{Max} and between M_{Max} and M_D

Place M in general equation equal to zero and solve for ϕ

$$\gamma r^3 \left(\frac{1}{2} - \frac{1}{4}\cos\phi - \frac{1}{2}\phi\sin\phi\right) = M = O$$

Therefore, $\phi \sin\phi + \frac{1}{2}\cos\phi = 1$

or $\phi = 50° — 36' — 45''$,
also $\phi = 146° — 19' — 25''$.

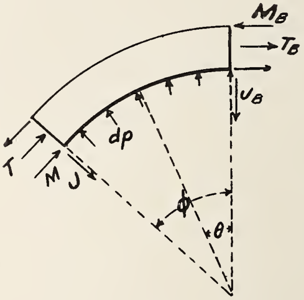


FIG. 4

Now, considering Fig. 4, we see that value of

$$d\,p = \gamma r^2 (1 - \cos\theta)\, d\,\theta.$$

Therefore the sum of the vertical components of all the $d\,p$'s between

$$O \text{ and } \phi = \int_0^\phi d\,p \cos\theta = \int_0^\phi \gamma r^2 (1 \cos\theta) \cos\theta\, d\,\theta$$

$$= \gamma r^2 \left(\sin\phi - \frac{1}{2}\phi - \frac{1}{4}\sin 2\phi\right)$$

And the sum of the horizontol components of all the $d\,p$'s between O and ϕ

$$= \int_0^\phi d\,p \sin\theta = \int_0^\phi \gamma\, r^2\,(1 - \cos\theta)\sin\theta\, d\,\theta$$

$$= -\gamma\, r^2 \left(\cos\theta\,\phi - 1 + \frac{\sin^2\phi}{2}\right)$$

In Fig. 4 place vertical components of the acting forces equal to zero.

Therefore,

$$J\cos\phi + T\sin\phi = \gamma\, r^2\,(\sin\phi - \frac{1}{2}\,\phi - \frac{1}{2}\sin\phi\cos\phi)$$

Placing horizontal components equal to zero,

$$J\sin\phi - T\cos\phi = \frac{3}{4}\,\gamma\, r^2 - \gamma\, r^2\cos\phi + \gamma\, r^2 - \frac{1}{2}\,\gamma\, r^2 \sin{}^2\phi$$

solving these equations for T and J we obtain:

$$T = \gamma\, r^2\,(1 - \frac{1}{2}\,\phi\sin\phi - \phi - \frac{1}{4}\cos\phi)$$

$$J = \gamma\, r^2\,(\frac{1}{2}\,\phi\cos\phi + \frac{1}{4}\sin\phi)$$

The above discussion has assumed that the pipe is just filled with water to the top. We can easily see that the bending moments are not affected by the water pressure after the top is passed. In other words, the bending moments induced in the shell are caused by the difference in pressure between the top and any other point chosen; and this difference remains constant for any head above the top. The tension in the shell, however, varies directly with the head and is equal to $H\,\gamma\, r$, where H is the head on the top of the pipe.

This amount must be added to the above obtained value of the tension to obtain the general expression.

Collecting the formulae we have

$$M = \gamma\, r^2\,(\frac{1}{2} - \frac{1}{4}\cos\phi \;\; \frac{1}{2}\,\phi\sin\phi)$$

$$T = H\,\gamma\, r + \gamma\, r^2\,(1 - \frac{1}{4}\cos\phi - \frac{1}{2}\,\phi\sin\phi)$$

$$J = \gamma\, r^2\,(\frac{1}{2}\,\phi\cos\phi + \frac{1}{4}\sin\phi)$$

$$M_B = \frac{1}{4}\,\gamma\, r^3$$

$$M_D = \frac{3}{4}\,\gamma\, r^3$$

$$M_{Max} = -.3203\,\gamma\, r^3$$

$$T_B = H\,\gamma\, r + \frac{3}{4}\,\gamma\, r^2$$

$$T_D = H\,\gamma\, r + \frac{5}{4}\,\gamma\, r^2$$

$$\phi_{\text{Max}} = 105^\circ - 13' - 45''.4$$

$$\phi_u = 50^\circ - 36' - 45''$$

$$\phi_L = 146^\circ - 19' - 25''$$

$$\Delta x = .0719 \frac{\gamma r^5}{E I}$$

$$\Delta y = .2337 \frac{\gamma r^5}{E I}$$

In order to show the results clearly let us plot a bending moment diagram. We can always express the bending moment in terms of the tension multiplied by the arm of the moment. Therefore, if we divide the bending moment at any point by the tension at the same point, we obtain the arm of the bending moment at that point.

Let $d\rho = \dfrac{M}{T}$ = arm of bending moment.

$$= \frac{\gamma r^3 \left(\frac{1}{2} - \frac{1}{4}\cos\phi \frac{1}{2}\phi\sin\phi\right)}{\gamma r \left\{ H + r\left(1 - \frac{1}{4}\cos\phi - \frac{1}{2}\phi\sin\phi\right)\right\}}$$

$$= \frac{r\left(\frac{1}{2} + k\right)}{\frac{H + r}{r} + k} \quad \text{where } k = -\frac{1}{4}\cos\phi - \frac{1}{2}\phi\sin\phi$$

Plotting the values of $d\delta$ radially, for different values of ϕ we can represent the bending moment as shown in Fig. 5. This curve is the equilibrium polygon for the assumed conditions.

The above formulae taken together with the formulae for the weight of the shell itself, a reference to which was made at the beginning of this paper, are extremely useful; in fact, absolutely necessary to the correct design of concrete pressure pipes of large diameter.

On account of the node points (points of zero bending moment) and points of maximum bending moment occurring at the same points, both for the weight of the water itself and the weight of the shell, and because the bending moments due to both causes are exactly proportional at all points on the circumference it follows that they may be readily combined. With the above formulae, therefore, and those for the weight of the shell the design of pressure pipes of large diameter becomes a comparatively simple matter.

The above method of analysis, based on the general formulae for continuous arch girders, may also be used to determine the stresses induced in the shell for different loads applied on the top and sides, such as back-fill, etc.

The writer is sorry that lack of time prevents him from entering more fully into the methods of combining the several

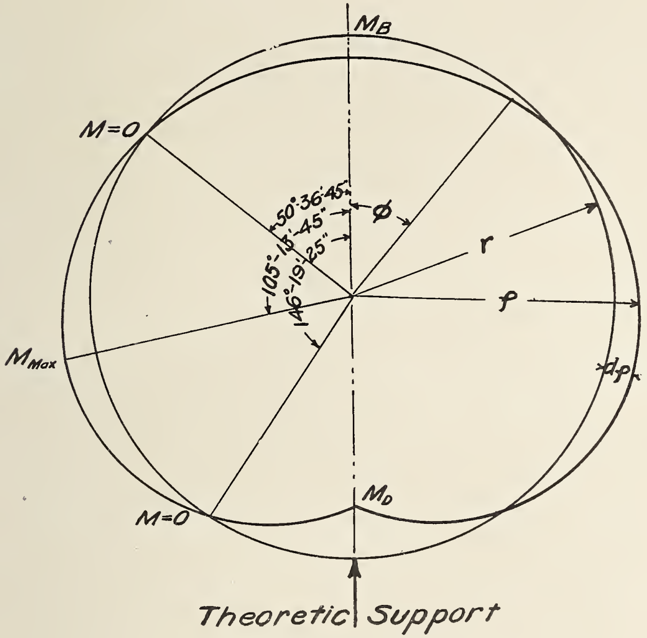


FIG 5

stresses due to weight of shell, weight of water, water pressure, back-fill and top loads, as many interesting problems arise in the application to an actual design.

RADIO-TELEGRAPHY.

L. T. RUTLEDGE, B.A.Sc.

All signalling at a distance necessitates the use of three distinct parts: the device which produces the signal, that which carries it, and that which receives it. These three essentials we may call the sender or transmitter, the line and the receiver. Now, in the case of wireless telegraphy, something in space is the medium of propagation, and it is the object of the writer to discuss the conditions which make it possible for telegrahpic messages to be sent from one continent to the other with seemingly nothing passing from one to the other.

The first point in this connection is to get a clear idea of the fields that are set up in space by electric currents and charges. It is well known that a current, even in a straight conductor, sets up an invisible magnetic field in the space surrounding it. In this case the field consists of magnetic lines that surround the conductor. Now let us briefly consider the state of the space that lies between any surface that is charged with a positive charge and the neighboring surface that is charged negatively. The dielectric, whether air or glass, between the two surfaces that are charged, is in a state of electric strain, there being electric lines of force through it from positive to negative, and these constitute an electric field.

Now consider a circuit in which there is an oscillating current. Fig. 1 represents a simple condenser made of two flat metal plates, with a layer of air between them. They are joined by a simple circuit made of bent brass rods, ending in polished balls with a spark gap between them, so as to be able to start oscillations by connecting to a suitable source, such as an induction coil. Just before a spark passes, one of the metal plates is highly positive and the other highly negative, and then there will be an electric field across the air space between them. When the spark occurs, the positive charge rushes round the circuit into the plate that was negative and then surges back again with incredible rapidity, oscillating along the conducting circuit. Each such rush constitutes a current, and as the successive rushes are in opposite directions, the conducting rods become the seat of an alternating current of high frequency. Therefore in the space surrounding the bent rods there will be set up an alternating magnetic field. The magnetic field surrounding the wire will be strongest when the rushing current is strongest, and this occurs precisely at the moment when the condenser has been emptied and before it is charged up again by the continuance of the rush. But the electric field, which will also be alternating, and which lies in the crevice between the plates, will be strongest when the rush either way is finished, and the charge in the condenser is at its height. So we here see that the

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* **Read before Electrical Club, University of Toronto, Nov. 1910.**

magnetic and electric fields occur at different places and have their maxima at different times. It has been experimentally proved that under such conditions no electric waves can be emitted; it here being taken for granted that electric oscillations occurring under the proper conditions give rise to what are known as "electric waves," a phenomenon which many years ago has been well studied and described by many eminent scientists.

Let the condenser of Fig. 1 be opened up into the form shown in Fig. 2, with the two metal plates, .WW., extended

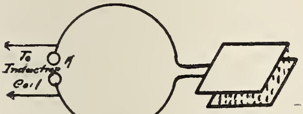

Fig. 1

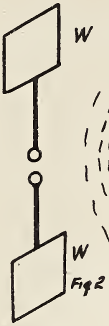

Fig 2

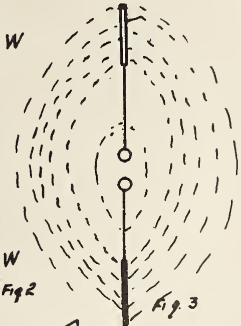

Fig. 3

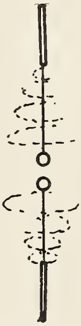

Fig 4

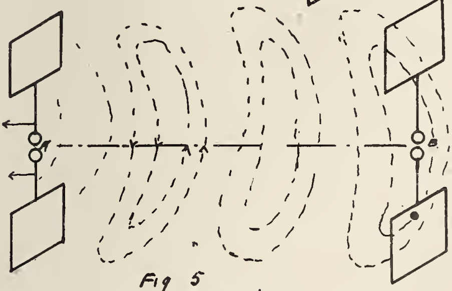

Fig 5

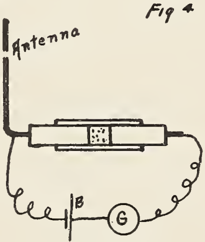

Fig 6

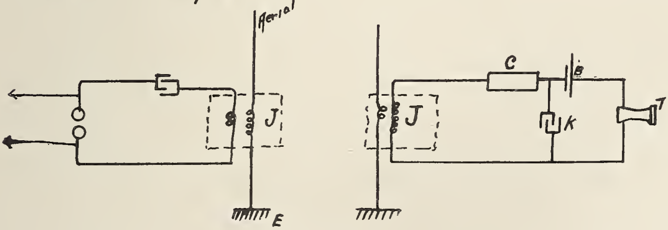

Fig. 7

out like wings, and conductor with spark gap, A, in the middle made straight. As before, air is the dielectric. When they are charged, there will be an electric field from one to the other as in Fig. 3. If a current were rushing up and down from one to the other, there would be a magnetic field, as shown in Fig. 4. Now, when a spark is made to pass, setting up a series of oscillations, the electric field between the wings will extend, as the dotted lines show, right across the space where the magnetic field will occur during the rushes of the current up and down the rod. The electric field will not have died away before the magnetic field has begun to grow, so that both kinds of fields can be present in the same space at the same time, and while the electric lines will be mainly parallel to the conductor the magnetic lines will be transverse whirls around it. For the production of electric waves it is necessary that there should be both an electric field and a magnetic field at the same point of space and at the same time. This simple apparatus is capable, then, of throwing off into the space surrounding it an electric wave at each oscillation. Such waves do not return back into the system, but go travelling off into space with the speed of light, following one another as in Fig. 5. The more the metal plates present of free surface, the more freely do they radiate off electric waves. If they consist of flat metal the electric waves radiate off more freely from the flat faces than from their ends or edges. If set vertical they radiate out mainly in front and behind, but they may be set horizontally at the ends of the system. The late Professor Hertz devised this simple apparatus in 1887 for the manufacture of electric waves. It is known as a Hertz Oscillator.

Now, to detect these waves, Hertz placed in another part of the room an exactly similar apparatus with two plates and a minute spark gap, as shown on the right of Fig. 5. The spark gap B was not more than 1-1000 inch, otherwise the induced electromotive force was not able to make the spark jump across the air space. Hertz, on placing an oscillator and a detector like these, a few feet apart in a room, found that a spark occurred at B every time a spark occurred at A. This induced emf. was seen to be due to waves emitted from the oscillator and caught by the detector. Hertz was also able to show that these electric waves could be reflected from a large sheet of metal or collected by a parabolic mirror or refracted through a prism of pitch; in fact, they behaved like waves of light, only they were quite invisible.

These results obtained by Hertz led other men to experiment. Branly discovered that a heap of metal filings possesses the very curious property that although they are usually a very bad conductor because of the innumerable imperfect contacts among the particles, they yet become a much better conductor when an electric spark is made anywhere near them. Lodge found that the imperfect contact made a pointed wire resting against a metal plate to be sensitive to the action of an electric wave. Such imperfect conductors are called coherers. Taking advantage of Branly's observations, Lodge constructed a coherer of metal filings enclosed in a small glass tube between metal rods inserted at the ends, and this proved very sensitive, but he found that it required to be tapped after each operation to cause the filings to decohere, and proposed methods of automatic tapping which will be touched on later.

The method in which the coherer was used to detect the electric signals is as follows: The coherer was connected to a voltaic cell and a galvanometer in series. The coherer has so poor a conductivity that practically no current flows. Directly an electric wave falls upon the coherer or upon the wires attached to it, it sets up oscillations, and probably also sets up minute sparks in the air gaps between the filings. Whether this is so or not, it increases the conductivity of the filings so that the cell is able to send enough current through the circuit as is detected by the galvanometer (see Fig 6.) Lodge found considerable advantage in fastening to the coherer an extended wire as an antenna to receive the wave. In his early experiments he put the whole apparatus in a tight metal box to exclude the effects of any stray waves, the only thing projecting out of the box being the receiving antenna. With such a coherer he was able to extend the distance between transmitter and receiver to two miles.

He also extended the distance by using at the spark gap a single polished ball between two smaller ones.

In the Hertz upright oscillator, as in Fig. 5, the capacity plates at the top and bottom ends of the oscillator are the places which become most highly charged, the middle part of the connecting system being as it were a node in the waves. The same would be true of the same apparatus if used as a detector. The ends are the places which receive the maximum charges of potential. The middle part is the seat of the strongest currents, and whole loops of waves are sent out. But this is no longer the case if the oscillator or receiver is earthed, as to the lower half, and the node in the electric wave occurs just above the earth and waves of which half are in the air are sent out.

This idea of having half the wave travelling in air and the other half in the ocean or earth is of great advantage. The waves maintain continuous contact with earth, are not sent through space, but undulate along the surface, and cannot be reflected by earth into space as they would be if the waves were closed upon themselves; so this prevents the dispersion of energy in any disadvantageous direction, and at the same time facilitates its transmission in the useful direction, that is to say, in the horizontal, and in practice it is found that the intensity of the wave does not diminish more rapidly than the simple inverse of the distance from the centre of emission.

Since the earth takes an essential part in the transmission of waves it must be of good conductivity; wet soil or sea. Earthed apparatus does not work over a dry desert. The movement of the half loops of electric waves outward from an earthed oscillator as distinguished from the non-earthed oscillator used by Hertz and Lodge, is hindered by a bad conductivity on the earth's surface, but is helped by the fairly good conductivity of the sea. On the other hand, for non-earthed oscillators emitting whole loops of waves, the conducting power of the earth is no help.

The first wireless telegraphing was done by Sir Oliver Lodge, who, in 1894, sent wireless signals through stone walls and from one building to another, using as a detector a filings coherer as described, the system being untuned. Signor Marconi at first made his experiments with a coherer put to earth in circuit with a single cell and a sensitive telegraphic relay, which in turn actuated an ordinary Morse instrument, printing dots and dashes. In 1898 Marconi adopted the plan now claimed essential to his system of using a tall mast like a lightning conductor, the lower side of the spark gap being connected to earth and called "the aerial wire," or "antenna," or "earthed vertical oscillator."

The frequency of the oscillations is determined by the capacity and self-induction of the apparatus and also by the length from the node to the ends and the surface presented. Also any evils introduced into it will increase its self-induction and lengthen the waves. An oscillator like Lodge's or Hertz's has relatively large surface and small self-induction and will radiate so freely that the wave train will die out after very few oscillations. Owing to the fact that the Marconi aerial resembles the Hertz oscillator in possessing a large radiation surface, it cannot send out such trains of waves as would be required for syntonic working, or in other words, it is necessary to tune the instruments and the aerial. In none of the early operations could tuning be secured, and they were liable to interference from stray disturbances in the atmosphere.

With regard to tuning we must observe that the receiving apparatus is a vibrator similar to the sender, and therefore on the first arrival of an electric impulse electrical vibrations will be produced in it, having periods similar to that of the receiving apparatus. The same effect will be produced with the arrival of each wave, and since the effects are additive, it is necessary that the arriving waves should have the same rhythm or period as those which are set up in the sky rods, otherwise the vibrations set up by the successive impulses will overlap each other, irregularly weakening each other, and producing what is called interference of waves. Therefore when waves are striking the rceiving apparatus it is the duty of the operator to vary the capacity and inductance of his apparatus so that his apparatus will vibrate with the same rhythm as the distant transmitting apparatus, and in practice the high clear note is found to be the one desired, that is, if a telephone were connected in the coherer circuit one should hear clear high notes for best working. When the receiving apparatus is so set as to receive messages it will generally be found that a hum can be heard in the telephone. Stray disturbances in the atmosphere, perhaps static disturbances, or stray waves emitted from some place or other cause this, and therefore if station A wishes to converse with station B the apparatus of the receiving station must be tuned such that the required message is heard above these other minor ones. As stated before, the high note is required for good working, and the higher the note the easier it is for the operator to distinguish it. Also in this connection it might be well to note that waves should not be damped. Damped waves diminish and die away after a few vibrations. Damping may be caused by too high resistance in conductors, spark gaps, etc. A high sky rod reduces damping and so does putting part of oscillator to earth. If a source of persistent oscillations could be applied, the receiving apparatus could be tuned to the sending apparatus, and thus the whole system be rendered far more sensitive for long-distance work. To do this the sending apparatus must in some way be linked up with an oscillation circuit, and the distant receiving apparatus should similarly be supplied with an oscillation circuit; then the two can be tuned to the same frequency of oscillation. There are more ways than one of associating the wave apparatus with an oscillation circuit. The most usual one is by means of an oscillation transformer, called in telegraphic language a "jigger," and is due to Sir Oliver Lodge. This induction transformer is a simple arrangement for a primary coil of one or two turns surrounding or surrounded by a secondary coil of a larger number of turns. A simple form of jigger is shown in Fig. 7; J is the jigger, represented by two separate spirals, K the condenser, C the coherer. When the primary coil is traversed by oscillations they induce other oscillations in the secondary circuit, but these last are feeble unless a condenser is put across the secondary terminals and the two circuits brought into resonance.

Besides the advantage gained by tuning, there is another advantage of putting the oscillation transformer into the receiving circuit. For at the node of the receiving aerial the potential is a minimum, and the current a maximum. Therefore as the coherer depends on the potential and not on the current, the node is a bad place to insert the coherer, as was done at first. By placing in the node the primary of the transformer and inserting the coherer in the secondary, the increased voltage so applied to the coherer was found to increase its sensitiveness considerably, and therefore greatly extended the range of working. Marconi being desirous of working over still greater distance, adopted (in 1899) the jigger into his arrangements, and was able to signal eighty-five miles. For transmitting oscillations the transformer was generally constructed as follows: It consisted of a square wooden frame wound over with a number of lengths of highly insulated, stranded copper cable, joined in parallel, so as to make a primary of one turn. Over this is wound a secondary of from five to ten turns. The oscillation transformer is usually immersed in oil.

Having obtained the syntonisation of the stations in such a manner that the receiving station will only answer to the wave emitted by a station tuned to its period, it will be easily understood that if there be several receiving stations, each one tuned to a different period of electrical oscillations, and whose corresponding length of wave is known at the sending station, this latter can tune its own apparatus in such a manner that the despatch shall be received by one determined station among these, and then modify the tuning in order to communicate with another, the message with the first having ceased, and so on.

The problem of multiple communication, that is to say, the communication simultaneously to several stations in any direction and in a similar radius of action, is therefore intimately associated with that of syntonisation. It will be easily understood that a given station will have greater importance even from the business point of view in proportion as the number of special stations with which it can communicate, be greater.

Marconi has contrived a way by which he can at one and the same time transmit from a single station several messages. In 1903, in Italy, he sent five messages at once from a single sky rod. As spoken of before, tuning can be accomplished by changing capacity, inductivity or both. Signor Marconi, for greater facility and certainty of action, causes conductors of different capacity and inductance to be thrown into contact with the aerial and having it arranged so that this can be done for each transmitting apparatus, then no two will have the same wave form and thus two or more signals can be leaving the aerial at the same time. The receivers can be similarly fixed so that each will take care of its own messages.

In passing from the theoretical discussion to a discussion of practical apparatus as is used by wireless companies, it might be stated that to fully discuss the theory of radio-telegraphy, higher mathematics should be made use of, as, for instance, to show relations existing between wave length and capacity. Also the formulae for induction frequency, wave length and capacity could be derived, but space is too limited for that phase of the subject.

An ordinary wireless station contains at least one transmitting set and one receiving set. If it is a station that is supposed to work within a radius of five hundred miles, the transmitting set will likely consist of a motor generator set, an oscillation transformer, a variable inductance and capacity in the form of coils and condensers, a spark, gap, a key, and an aerial. The receiving apparatus has the same aerial as part of it, a detector of some kind, as, for example, the coherer, a tuning device consisting of inductance coils and condensers, a telephone or some recording telegraphic device or sounder, including the necessary wiring and switches. A large transmitting station, such as a trans-Atlantic one, needs more apparatus than a simple motor generator set for generation of power. In such a station we find the accumulator house, the condenser house, a boiler room, engine room, an operating room and a high tension room and an arial covering several acres, all of which will be discussed in detail.

Transmitting Apparatus.

For short-distance spark telegraphy the necessary high potential is always obtained by the use of an induction coil or transformer; either a single instrument or a number of induction coils or transformers may be employed, having their secondary circuits joined in series and their primary in parallel.

The most usual appliance is an induction coil of the ordinary type, having a spark length of ten inches and taking current from storage batteries or from a small single phase alternator. The induction coil is placed on the table in the transmitting station, or it may be fastened to the wall. It may be operated either by alternating current or an interrupted continuous current.

The next element in the transmitting apparatus is the signalling key for interrupting the primary circuit in accordance with the signals of the Morse alphabet or Continental code. This must be a quick break key with a long ebonite handle easily operated, and has generally a magnetic blow-out in connection with the platinum terminals between which the interruption takes place. Marconi has tried several kinds of keys. Some have the points touch in air, some in a recipient filled with paraffin. He uses in his key circuit a condenser in shunt so as to do away with self-induction sparks on opening or closing the circuit. Also if an alternator is used a provision is made to save it, since it is running all the time. Marconi puts in parallel with the key a reaction coil whose reactance when its core is completely immersed is such as to damp entirely the exciting current. Every time the key is closed the current excites the primary of the transformer and discharges are produced and on the other hand when the key is raised, the exciting current is annulled by the reactance and the discharges cease without any necessity of altering the working of the alternator.

Reference has previously been made to the oscillating transformer or jigger. Marconi prefers to connect the aerial inductively with the energy-storing circuit by the oscillation transformer. It consists of a few turns of primary winding wound on a wooden frame and more turns of a secondary connected in series with the aerial that has a variable inductance between this secondary winding and the earth connection. This last mentioned inductance is really a turning coil. A condenser is put in series with the line leading to one end of the primary of the jigger and the spark gap is connected in parallel with the primary coil having this condenser in a line between the spark gap and primary winding.

Reference might here be made to what happens when two oscillation circuits are connected together inductively and in tune with one another: oscillations set up in one circuit results in the production of oscillations in both circuits, having two frequencies, one greater and the other less than the natural frequency of each circuit when separate. Hence when employing an induction coupled antenna which has been syntonised with the condenser circuit, it is necessary to bear in mind that oscillations of two frequencies are set up in the antenna and waves of two wave lengths radiated from it, one greater and the other less than the wave length corresponding to the natural frequency of the antenna taken alone. One of these waves has greater amplitude than the other, the longest wave length being the least damped and therefore having the greatest integral value. The wave lengths approximate to one another in proportion as the coupling is made weaker but then they also diminish in amplitude so that by the employment of a weak coupling, which can be done by separating the primary and secondary of this transmitting jigger, we get a radiation which is a little feebler but of a single wave length, whereas by close coupling we get more powerful waves but waves of two wave lengths radiated, and the receiving antenna must accordingly be syntonised to one or other of these wave lengths.

As regards condensers for the oscillation circuit, although a Leyden jar is a bulky form of condenser in comparison with its energy storing power, nevertheless its simplicity still recommends it. The main condenser consists of a battery of them joined partly in parallel and partly in series. It is very important that the capacity of the condenser is exactly known and the jars selected so as to be exactly equal to eliminate as far as possible electric brush discharges. The condenser can be constructed of plates immersed in oil. Brush discharges are thereby prevented and accuracy of tuning is secured by preserving a constant known capacity in the condenser circuit. Exact syntonisation between condenser circuit and aerial circuit is absolutely necessary. Other things being equal the radiation will be in proportion to the mean square value of the current flowing into the base of the antenna. The current may be measured by inserting in that point a hot wire ammeter.

Another important element in the transmitting arrangement is the spark discharge. When large capacities are being employed the noise of this spark is distressing and any one who understands the code can read the messages at a great distance. The spark balls should be enclosed and have alkaline material close by for absorbing acid vapors or gases. It is of great advantage to blow a jet of air upon the spark gap to quench the arc. A spark gap can be done away with and a Poulsen arc substituted in its place. This is a device invented (in 1903) by Poulsen of Copenhagen. He produced an electric arc between a carbon rod as a negative and a copper rod as a positive terminal, the latter being kept cool by water circulation. This apparatus gives very powerful undamped oscillations, the frequency of which by a proper selection of capacity and inductance, can be made to be as high as a million or more, and quite within the range of those required for radio-telegraphic work.

Marconi in his large stations has made use of a new device for discharging, known as the High Speed Discharger. In one form of it, there are caused to rotate rapidly by electric motors or other means two discs with perforations. Between these, and insulated from them, another disc (with its plane at right angles to the other two) rotates at a high speed. This plane and the two discs are connected in the circuit with inductances and condensers. At a certain potential, the condensers discharge with oscillations across one or other of the air gaps between the rapidly revolving disc. The arc discharge which attempts to follow in the track of the oscillation is however prevented by the rotation of the discs from taking place. A very high piercing note is produced by this sparking apparatus.

The length of antenna varies with the size of the station. A small five kilowatt station for operating up to 500 miles would have a tower about 150 feet high, situated on some high point, and having bare wires leading in a downward direction. Another scheme is to use two towers joined by bare wires and a tie-arrangement leading to receiver. In the very large stations as for example the Glace Bay Station, the Clifden Station on the coast of Ireland, or the Poldu station of Cornwall, more extensive aerial is required. At the Glace Bay Station at Cape Breton Marconi has four towers built with a cone shaped envelope of wires suspended from the top of the towers, thus making it possible to have a large radiation surface. The aerial apparatus at the German station of Nauen near Berlin is pretty extensive. That company uses there a steel tower 328 feet high built so as not to vibrate, the tower being triangular and thirteen feet to a side. The tower is insulated from the earth as well as the guy cables. The antenna is sloped like an umbrella, the tower representing the rod. The aerial is divided into six sections, the upper part consisting of six sections of 54 wire cables, nine in each of the six sections. At a point 82 feet from the top of the tower each cable divides into three so that there are 162 cables altogether. The aggregate surface enclosed is fifteen acres. The cables are insulated from the ground and led in parallel to the station. The ground contact is made through a system of 108 wires buried in low wet ground. These wires divide as they diverge, and the area enveloped is thirty-one acres. There are altogether 324 wires in the ground. Most of Marconi trans-Atlantic stations are situated near the coast in the very wettest piece of ground he can find in the region. The station at Glace Bay is in a very desolate, lonely swampy place.

Just here it might be well to speak of the transmitting apparatus of the Nauen station. The operating rooms occupy a brick building, the ground floor of which contains the dynamo, the transmitting office and the work ship. All the high tension apparatus is placed in the second storey where it is free from dampness and hence more perfectly insulated. The power is furnished by a 35 H.P. engine which drives a single phase alternator coupled to an exciter on the same shaft. This generator at a speed of 750 R.P.M., furnishes 25 kilowatts of electrical power in the form of a single phase current of 50 cycles per second. In the circuit are fusible plugs, voltmeter, ammeter, frequency indicator, a transmitting and cut out relay. Four large inductance coils are in the dynamo circuit, in addition to the four transformers which produce the high tension transmitting current. The transmitting circuit also includes a battery of 360 Leyden jars arranged three in series by 120 abreast and having an aggregate capacity of 400,000 coulombs.

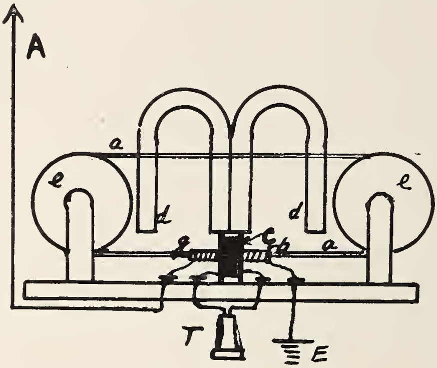

Fig 8.
MAGNETIC DETECTOR

This station just described has sent messages 1500 miles over water and received telephonic messages from St. Petersburg a distance of 840 miles.

Marconi, to transmit messages across the Atlantic, uses an installation of 75 kilowatt capacity, the voltage being transformed up to about a quarter to half a million volts.

Receiving Apparatus.

The discussion of receiving apparatus centres around that of a special part of it known as the detector. There are indeed many forms of detector of electro-magnet waves from the old filings coherer to the latest inventions of magnetic and electrolytic detector and lastly the famous Fleming Valve Receiver.

Marconi first used a coherer as a detector. It had nickel filings with four per cent. silver in it. The dimensions of such a coherer are 1½ inch long, 1-10 inch internal bore with silver stoppers 1-5 inch long and the space between for filings being 1-50 inch. With this delicate apparatus 1.5 volts was the maximum voltage he used and one milli ampere was the maximum current sent through by a single cell. He used a decoherer in the form of a hammer actuated by an electromagnet which just struck a rubber pad on the coherer tube.

The second type of coherer used was a magnetic one. It was discovered that electric waves can exercise a demagnetizing influence upon a highly magnetized small steel needle and a magnetic detector of waves on this principle was made. Marconi for telegraphic work invented an improved form of detector a diagram of which is given in *fig.* 8, made as follows: Two wooden discs e,e, grooved on the edges are driven mechanically by clock work. An endless band a,r, made of a bundle of fine silk-covered iron wires, is arranged like a belt over these pulleys and moves forward at the rate of about three inches per second. At one place the iron band passes through a glass tube, g.b., on which is wound a coil of insulated wire through which oscillations can be passed and this coil is embraced in the centre of another coil, c., connected with the telephone T. A. pair of horse-shoe magnets are placed with their similar poles together opposite to the last mentioned coil as shown in the diagram. If electric oscillations pass through the coil wound round the band they change the magnetic state of the iron and generate an induced in the secondary coil and hence a current and sound in the telephone. The operation of this instrument was considered by Marconi to be due to the power of electric oscillations passing through the coil surrounding magnetized iron to annul the hysteresis of the iron. A magnetic detector like this is found to work, when there are static disturbances a little better than some other detectors.

The third and present detector used by Marconi is known as the Fleming Valve Receiver, invented by J. A. Fleming, M.A., D.Sc., Pender Professor of Electrical Engineering in the University of London. He first used an ordinary incandescent lamp with carbon filament and having a metal plate included in the glass bulb or a metal cylinder placed around the filament, the said plate or cylinder being attached to an independent insulated platinum wire T, sealed through the glass. When the carbon is rendered incandescent by electric current, the space between the filament and th plate, occupied by highly rarefied gas possesses a unilateral conductivity and negative electricity will pass from the filament to the plate but not in the opposite direction. This depends upon the well-known fact that carbon in a state of high incandescence liberates negative ions. A practical lamp has been made—a small incandescent lamp with a rather thick filament taking about 2 amperes at a terminal voltage of 12 volts. *Fig.* 9 shows how this detector is used in radio-telegraphy work. The antenna A, is coupled through an oscillation transformer with a circuit which includes the valve, O, and the fine wire coil of an ordinary 10-inch spark induction coil, I, the low resistance coil of which is in circuit with the telephone T. Condensers are placed across the secondary circuit of the oscillation transformer and also in series with the fine wire coil of the large induction coil. By suitable adjustments of the capacity of this condenser the circuits are brought into resonance. Oscillations taking place in the antenna, due to the impact of electric waves upon them are then transformed by the jigger, rectified by the oscillation valve and sent through the fine wire coil of the large induction coil in the form of a unidirectional but intermittent current and these oscillations are again transformed up in current value by the large induction coil. In this way a sound is created in the telephone. So used, the oscillation valve becomes one of the best long distance receivers for electric waves yet devised .

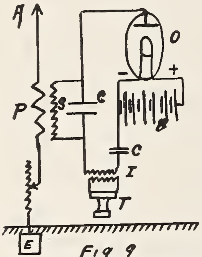

Fig 9
CONNECTION FOR
FLEMING VALVE

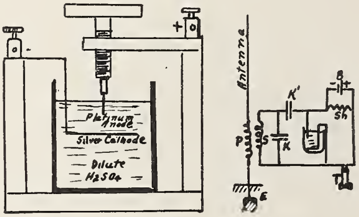

Fig. 10
ELECTROLYTIC DETECTOR

At the top of the departmental store of John Eaton, Esq., Toronto, is a wireless station which has all three of the Marconi type of detector installed and in first class condition, the station being of two kilowatt capacity. Power is furnished by a motor-generator set at 500 volts and the voltage is transformed to 12000 by the oscillation transformer. The spark used is five-eights inch long, being two gaps in series. The operator can intercept messages sent out from the Atlantic stations near New York and is in daily communication with the Clarke Great Lake stations. The high efficiency of this station is due to the excellent tuning apparatus a wiring diagram of which is shown in *Fig.* 11. The Fleming valve is the detector shown. Two valves are installed, only one being in use at a time. Neverthless they find the magnetic detector the better during static disturbances in the atmosphere. A fine adjustment for tuning is to be had in the billi-condenser. When the operator is just listening the switch is on the stand-by side but when communication is opened up with any one particular place it is thrown over to the tuning side and the receiving apparatus is tuned to read the required message, the tuning cutting out all stray disturbances and messages of other stations. The wave length for this outfit is about 300 metres. It possesses an advantage over the Clarke system in the operator being able to receive and transmit at practically the same instant: all that is necessary to receive is to stop working the key whereas in the Clarke Lake stations a lever has to be moved which (to accomplish) takes a little time.

Besides the form of detector used by Marconi an American company headed by Fessenden uses an electrolytic detector. It is shown in *Fig.* 10. It consists essentially of a vessel having as one electrode a very fine short wire of platinum offering therefore an extremely small surface. This electrode is generally made the anode. The other electrode is a silver plate. The electrolyte is sulphuric acid. The cell becomes polarized but electric oscillations depolarize it, thus allowing a current to circulate and giving rise to a sound in the telephone. When the wave ceases it is again polarized. It is quite automatic in action and very efficient.

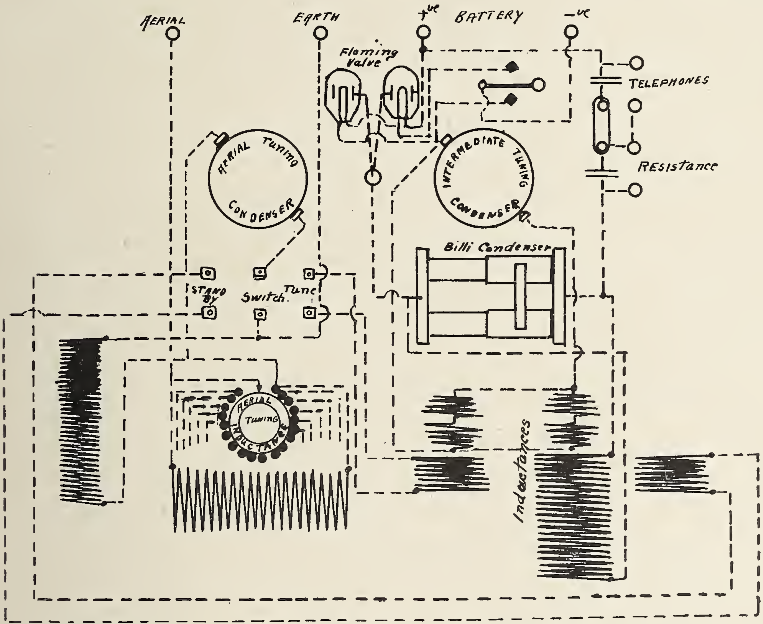

FIG 11

DIAGRAM OF CONNECTION OF A MARCONI RECEIVING APPARATUS USING FLEMING VALVE

Effect of Atmospheric Conditions and Daylight.

The first attempt to conduct radio-telegraphy extending over many hundreds of miles revealed the important influence that atmospheric conditions have upon such telegraphy, especially the effect of sunlight upon it.

Marconi conducted experiments on board S. S. Philadelphia on the Atlantic. He noticed that it was possible to receive signals by night when they could not be detected by day. He found that there was very little difference in the signals received by day and by night until he was 500 miles from Poldu. After that, day signals began to weaken and at 1500 miles were hardly perceptible. At daybreak the effect was worse. This is attributed to the fact that light dissipates negative charges of electricity. Some scientists say that the atmosphere especially under the influence of daylight is in a state of ionization and it has been shown that these point charges of negative and positive electricity are set in motion by long electric waves travelling through space and they therefore partially absorb the wave energy.

On account of this effect of daylight messages are sent mostly at night, Press messages being sent from 10 p.m. to 1 a.m.

Another important fact could be mentioned in connection with long distance work and that is in the small degree to which the curvature of the earth seems to affect intercommunication between stations employing earth-connected antenna. It is well known that rays of light and sound are diffracted to some extent around obstacles but the long Hertzian waves from an earthed antenna appear to pass round a one-eighth part of the circumference of the earth without extravagant diminution of amplitude other than that due to distance and atmospheric absorption. The possible cause of the advantageous transmission round the terrestrial sphere is due to the earth connection both of the transmitting and receiving antennae, whereby both these antennae and the earth are practically converted into a single oscillator.

Radio-telegraphy like any other branch of electro-technics has its unsolved problems and it can not be said that a complete explanation of the nature of the propagation of electro-magnetic waves over and round the surface of our globe has been reached which is beyond dispute.

CHICAGO'S SHIP AND DRAINAGE CANAL.*

The Engineering Society of the University of Toronto were afforded a highly instructive address and a rare opportunity on December 12th, when Mr. Isham Randolph, C.E., delivered an illustrated address on Chicago's Ship and Sanitary Canal. While the address was exceedingly comprehensive, it was evident, as Mr. Randolph said, that so vast an enterprise could not be justly dealt with in one address. In fact, Mr. Randolph said the subject could be treated to more advantage under several heads, as, metropolitan, state, interstate, national, and international. In the course of his address Mr. Randolph said Chicago is but 74 years old and the great problems arising from sudden growth may be well imagined. He first took charge of Chicago's work in 1893, a few months after the great fire. At that time Chicago was a straggling sort of a city of about 400,000 population. Streets, in many cases, were below water level an dtremendous operations have taken place to put them in their present condition. Lake Michigan has always been Chicago's source of drinking water. The first lake tunnel ran two miles into the lake, but this was later regarded as insufficient and it was run 2 miles further out. At present there are several running out 4 miles from shore. In 1886 there was a commission appointed concerning this matter of sewage. This commission considered three propositions, (1) an intercepting sewer for conducting sewage to southern part of the lake, (2) a settling basin land filtration plant, but as this affected territory belonging to Indiana that state raised objection to this, (3) carrying the sewage donw the Illinois valley. But with the failure of these propositions the present problem arose. In 1889 the Legislature of Illinois passed a sanitary law, which materially affected Chicago's problem. Whereas 20,000 cubic feet of water per minute was obtainable, they planned a channel for obtaining 600,000 cubic feet per minute.

This canal was to be 200 feet wide on the bottom and 18 feet deep, but in reality it was 202 feet wide at bottom and 22 feet maximum depth. Through the rock the channel was 160 feet wide at bottom and minimum depth was 22 feet. In the rock there was a slope of 2¾ inches per mile and in the clay and sod a slope of about 1½ inches per mile. The cut was made through the rock with a channelling machine and was taken out in 3 stokes with widths at the bottom of 160 feet, 161 feet and 162 feet respectively, these offsets being allowed for the proper manipulation of t he channelling machine. Mr. Randolph was connected with this work for over fourteen years and it assumed enormous proportions during that time. One might reasonably ask whether this enormous expenditure was merited, for the sanitary district of Chicago has an area of only 356 square miles

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* Courtesy of "The Canadian Engineer," Toronto.

.64 of 1 per cent. of the area of the State of Illinois. This comparatively litle area expended $63,000,000 for his prodigious undertaking. The report of the health commissioner of Chicago will perhaps tell whether this really was a paying proposition. The report says that in 1891 Chicago had about the highest death rate from typhoid of any city. The result of these sewage improvements was that from 64.1 per 100,000 population, the death rate in Chicago for typhoid decreased to 23.5 per 100,000 population. And from having the highest death rate of any city it now has about the lowest, having only 15.6 per 1000,000 death rate. According to the report of the health commissioner, 11,148 typhoid deaths had been prevented in 9 years by this system. Mr. Randolph, in his address, expressed the wish that Toronto had such a drainage canal.

The Chicago ship canal is eventually 200 feet wide, 26 ft. deep in mid-stream and 18 ft. deep at the banks, and some 28 miles long. Mr. Randolph has many exceedingly interesting slides of the works, a remarkable feature being the description of the many various appliances used and in some cases devised for the first time to facilitate in the excavating and dredging on this work. Among some of the most interesting slides were those of the Brown level conveyer, which would often complete its operation in 52 seconds in handling 10,000 pounds. At Lockport there are seven gates, interesting from size. They fill gaps of 32 feet, are 20 feet high, have a weight of 62,000 pounds. Two men can raise and lower them in 15-foot pressure of water. The "Bear trap" dam at Lockport is also a remarkable feature—it is 160 feet on the crest, has 12 feet oscillation and the hinges are anchored 20 feet. The placing of this interesting type of structure at Lockport met with much opposition from commissioners and engineers alike and they predicted it would be a failure. It is, however, a decided success. There is also on this canal the so-called "Butterfly" dam, the only one of its kind in the world. It is 184 feet long, 34 feet high and has a pressure on the bottom, when closed, of 3,776,000 pounds. Mr. Randolph solved the hard problems of successful dredging by using the hydraulic dredge. This wonderful machine worked so well that another was built on the works. With the hydraulic dredge the contractors were able to remove 1,400,000 cubic yards of material at a cost of about 5 cents a yard. The Mississippi Navigation Commission following the example of Mr. Randolph has since employed the hydraulic dredge and this is making the navigation of the Mississippi possible. The dredge as used on the Mississippi cost $150,000 and 1,500 yards an hour can be removed with it. The cableway, an invention which was conceived on this Chicago's work, is another mechanical aid that has helped the wor kof excavation in engineering. The aerial dump has done marvels since its invention. Such appliances and the channelling machine, which on the Chicago work cut a gash of ⅜ inch and did 100 superficial feet a day, have made the work of excavation less tedious, and in some cases, at all possible.

In the Panama they are far exceeding now work done on the Chicago canal. This year they have excavated 135 million cubic yards. They excavated only 66 million last year and only 37 million cubic yards the year before last, so a tremendous progress is shown in the speed of excavating. Bridge work over the Chicago River has been very extensive. Eleven of the rolling lift type have been built across the Chicaga and more will be built. The principle of this very efficient bridge is that as the channel span opens the approach span drops. This type has been found very satisfactory.

Mr. Randolph's lecture was listened to with great interest by student and instructor alike, and a hearty vote of thanks extended him by the Society.

THE ENGINEERS' CLUB OF TORONTO.

C. R. Young, B.A.Sc.

For some years past various unsuccessful efforts have been made to establish in Toronto a club offering to engineers, architects, surveyors, chemists, and others engaged in applied science pursuits, all the privileges of the usual social club with technical advantages as well. It has been the dream of almost every member of the original Engineers' Club, incorporated under the Benevolent Societies' Act in 1902, that sometime and somehow the Club should expand into an institution occupying and possibly owning a club house of its own, of sufficient capacity to accommodate within its walls the various technical organizations existing and holding meetings in Toronto. In spite of the many sincere and earnest attempts to bring about this extension, the monetary difficulties in the way proved too much for those who first interested themselves in the commendable undertaking.

Finally, in the early part of the year 1910, a movement was set on foot aiming at the establishment of a "Social Club for Technically Trained Men." The final name was left to be chosen later.

It was recognized that with a membership drawn from engineers and surveyors alone who, up to that time had composed the Engineers' Club, it would be impossible to maintain an advanced Engineers' Club, and that the co-operation of architects, industrial and assaying chemists and all technically trained men working along applied science lines, as well as business men of allied pursuits, must be secured.

It was the intention of the promoters from the first that should the required support be pledged, at the proper time the existing Engineers' Club should be approached, and the two bodies united under a common name, and on a basis equitable to all, and with the strictest justice to each and every member of the original club.

In its early stages the proposition met with much success, and in the course of some four months the names of 360 men, including members of the existing Engineers' Club were secured, who agreed to join the new organization. At this stage, however, an insurmountable difficulty developed—that of securing a charter suitable for such a Club. Finally after much consideration, the organization committee of the "Social Club for Technically Trained" men informed the Engineers' Club that a charter carrying with it the usual club privileges would be more likely granted were it sought, not by the Social Club, but by the existing Engineers' Club, and with this the former organization ceased activity.

Accordingly, at a regularly-called meeting on August 5th., the Engineers' Club of Toronto appointed seven members to apply for a charter under the Ontario Companies' Act, and to follow out, if possible, the procedure essential to the establishment of a Club on the proper basis. It was tacitly agreed that the routine of the Club's business should in the meantime, be discharged by the old Executive Committee.

The desired charter was granted, after much unavoidable postponement, on September 27th., and the following seven members were named therein as provisional directors: A. B. Barry, C. M. Canniff, Willis Chipman, John Galbraith, J. G. Sing, J. B. Tyrrell, and A. J. Van Nostrand. On November 15th, the provisional directors enacted, under seal, after careful consideration and many amendments, a code of new bylaws suitable for the prospective wider life and extended membership of the Club, basing them upon the draft of the "Social Club for Technically Trained Men." These By-laws were finally adopted, without further alteration at a duly called meeting of the Club on December 1st., and the re-organized Club at last began its existence.

At this meeting the directorate was increased from seven to fifteen, the additional eight directors being drawn from the membership of the original Engineer's Club for obvious reasons. The full list thus became as follows: R. A. Baldwin, S. P. Biggs, W. A. Bucke, C. M. Canniff, Willis Chipman, John Galbraith, W. A. Hare, C. H. Heys, E. A. James, J. G. Sing, C. B. Smith, L. J Street, J. B. Tyrrell, A. J. Van Nostrand, and C. R. Young. These directors hold office till February 2nd, 1911, when the first regular annual election will take place, and when it will be possible to secure full representation on the Board, of all the interests concerned.

The provisions of the By-laws respecting membership will, no doubt, be of interest. It is stipulated that the Club shall be composed of engineers, architects, surveyors, industrial chemists, and others, who may be connected with or interested in engineering or allied pursuits. The membership of the Club is limited to 800, composed of 500 resident, 200 non-resident, 25 life, and 75 associate members. Ordinary resident members pay an entrance fee of $50, and an annual fee of $30, while for non-resident members the corresponding fees are $25 and $20. The annual fee is reduced in the two cases to $25 and $15 respectively for prompt payment. Each member must be at least 25 years of age.

The members of the original Engineer's Club are given preferential treatment to the extent of the remission of the entrance fee, since assets of considerable value were automatically transferred to the re-organized Club, on its incorporation under the Ontario Companies' Act. Those members of the old Club who, for any reason, do not wish to take full advantage of the extended privileges offered by the new Club, are, on payment of an annual fee of $5, entitled to the use of the Library, reading room, and lecture hall. The improvements which will be effected in these privileges will considerably enhance the benefits enjoyed by the members of the old Club.

Very soon after the adoption of the By-laws by the members of the Club, a Directors' meeting was held at which officers and members of standing committees were elected and other important business was transacted. The officers elected to hold office till February 2nd, 1911, were: President, C. M. Canniff; First Vice-President, Willis Chipman; Second Vice-President, A. J. Van Nostrand; Treasurer, L. J. Street. R. B. Wolsey was appointed permanent secretary of the club.

It was also decided to engage under a lease renewable on the present terms, for a period not exceeding two years the rooms on the second and third floors of 90-98 King Street West, including the rooms occupied in the past by the old Engineer's Club and the Ontario Association of Architects. These rooms are now being decorated and furnished in a manner suitable for the requirements of the new Club.

The advantage offered by the re-organized Engineer's Club cannot fail to prove highly attractive to technically trained men. With a down-town social club there will be an opportunity for engineers, architects, surveyors, chemists, and those whose pursuits bring them into contact with technically trained men, to meet and become better acquainted. Here members will be in a position to suitably entertain their business friends and clients at luncheon, diner, or otherwise; and out-of-town members may meet their city associates and clients and transact their business. To this end, it is proposed to provide, in conformity with a suitable standard of comfort and elegance, a Grill Room, Smoking Room, Sitting Rooms, Billiard and Card Rooms, and Private

Conference Rooms. A further extension of privileges will be afforded by affiliating with engineering clubs of other cities, and in return for the hospitality extended to Toronto engineers, visiting members of the engineering and allied professions will be entertained here in a befitting manner. Dormitories are being provided to accommodate such visitors as may wish to lodge in the club house during their stay in the city.

While the social privileges of the new club have been first mentioned, the technical side of its activity will by no means be neglected. A reading room, properly isolated in a quiet part of the building will be amply furnished with technical and other journals and magazines, and a first-class technical library will be gradually built up. In this work the various technical societies, meeting in Toronto, will co-operate with a view to economizing resources and avoiding duplication. The lecture room will be used by these organizations for their meetings, and the Engineer's Club itself will provide a technical programme during the winter months. Papers read at its meetings' will probably be printed later in the form of proceedings.

A proposal which will, no doubt, be carried into effect, and which will enhance the usefulness of the club, is the establishment of a bureau of information concerning technical work to be done, and men fitted by training to do such work.

A club affording privileges of this character, and free from politics or other clique-forming influences will undoubtedly appeal to all those whose pursuits qualify them for membership. When it is remembered that practically all the benefits offered by the regular social clubs are provided in the Engineer's Club of Toronto, on a reasonably comfortable and elegant scale, and at a fee much less than is ordinarily required by such clubs, it is apparent that the limit of membership is likely to be reached very soon after the re-organized club opens its doors.

THE TEMISKAMING S.P.S. DINNER.

The rapid advance of mining interests in Northern Ontario, and the equal rapidity with which many of our graduates realized the value of the same, were spoken and unspoken lines of thought at a gathering held by them on December 20th., the event of the First Annual Temiskaming S.P.S. dinner. Although the number present did not include all graduates who resided in the district, the dinner was well attended, a huge success, and thoroughly enjoyed.

The toast to "The King" was proposed by Mr. Robert Bryce. In proposing the toast to "The Faculty and Engineering Professions," Mr. C. H. Fullerton drew attention to the increasing importance of the industry of mining, and expressed it as the unanimous opinion of graduates in the Temiskaming district that, in view of the fact that there is at present only one professor and no lecturers in the Department of Mining of the University, something should be done towards increasing the staff of this Department. He reinforced his remarks by stating that this year the class in fourth year Mining, numbers nineteen, and by comparing it with the same class three years ago, consisting as it did of two members. The toast was fittingly responded to by Mr. A. D. Campbell, president of the Engineering Society.

Mr. H. T. Routley proposed the toast to "Our Guests." In replying, Dean Galbraith congratulated the graduates on their achievements in the north country and thanked them for the reception accorded him, and the extreme pleasure he experienced as their guest. He related some interesting reminiscences of a trip into the Temiskaming country some six years ago, before mining in Cobalt had come into existence.

"Sister Institutions," proposed by Mr. E. V. Neelands, was responded to by Mr. W. S. Dobbs, representing Queen's Unievrsity. Mr. A. A. Cole, who was to have represented McGill, was unable to be present. Messrs. Thorne, Jupp, and Sutcliffe were called upon to respond to "Our Wives and Sweethearts" proposed by Mr. B. Neilly.

The dinner was such a splendid success that its annual recurrence will undoubtedly be looked forward to with interest.

In addition to the banquet, the visit of Dr. Galbraith comprised a trip underground at the O'Brien and Crown Reserve mines, and through the concentrating mills at the O'Brien, Silver Cliff and Nova Scotia properties.

It might be well to cite a few figures from an agricultural pamphlet, published a few months ago by the Ontario Legislative Assembly, regarding the rapid growth of the Temiskaming District.

"So recently as six years ago there were but 2,000 people in Temiskaming, while now there are between 50,000 and 60,000.

Englehart, a divisional point of the T. and N. O. Railway, is

25 miles north of New Liskeard; only four years old, it has a population of about 800, and is a promising agricultural centre. Westward, at the terminus of the branch line of the T. and N. O. from Englehart, is Charlton, a thriving village at the foot of Long Lake.

New Liskeard, on the T. and N. O., at the head of Lake Temiskaming, is 113 miles north of North Bay, and 340 miles north of Toronto; its population is 3,000, it has several important industries, and is in the midst of a large, well-settled agricultural district.

Haileybury, five miles to the south, is an attractive residential town, with a population of 4,000.

Cobalt, four or five miles farther south, has world-wide fame for its deposits of silver, being one of the most important mineral deposits discovered in the last forty years. Population, 5,500. Farther south is the growing town of Latchford."

It is also interesting to note that practically four-fifths of the land surveying in Temiskaming District is done by "School" men. The firm of Routley, Summers, and Malcolmson have surveyed over 700 mining claims during the past two years. Sutcliffe and Neelands, besides doing a large land survey practice, are municipal engineers of Cobalt, New Liskeard and Cochrane.

In another department is given a list of graduates in this section of Northern Ontario.

METHODS OF SECURING MAXIMUM EFFICIENCY IN MANUFACTURING AND CONSTRUCTION.

By William M. Towle, B.S.*

Much is being said and written about conservation of natural resources. It is time that the American people paid more attention to the preservation of their heritage. With the great extent of territory and wealth of natural resources a tendency to run over and pick out the best and leave the rest to destruction and waste has been developed. In the manufacturing industries with the abundant supply of raw material and good home markets this same tendency is shown. Now when protection is lowered and the markets of the world are attracting attention it is necessary to consider the costs of manufacturing in all the details.

The cost of the manufactured product is made up of the cost of the raw material, labor, supervision, interest, and depreciation of plant, and expense of operating. In the ultimate analysis of the cost it will be found that labor represents nearly the whole amount, for the raw material before any labor is put upon it is but a small fraction of the whole cost of the article. Therefore, to reduce the cost of the finished product it is necessary to increase the efficiency of labor as no one wishes to reduce the wages of the laborer. Many schemes have been thought out and tried to accomplish this desired result. The most effort has been put on the wage side of the problem. As a general thing these schemes have been successful only when carried out by their originators or by some one in full sympathy with the plan.

The principal plans for rewarding labor are the day's-work, piece-work, premium or bonus, and profit sharing. The day's-work plan by which the laborer is paid a stipulated sum for the hour, day, or week, is the plan liked best by the workmen, for as a general thing they are willing to give a fair day's work for a fair day's pay. They look upon all other plans as methods to get more work out of them for the same money. While this is true to a certain extent, the other plans are mutually beneficial. The workman who is ambitious and willing to work harder gets more wages, and the manufacturer gets more work done with the same plant, thereby increasing the profits on the capital invested.

The profit-sharing plan, the most beautiful in theory is perhaps the poorest in practice. There are drawbacks in making a stockholder of an employee. While he is doing a good day's work the other workmen will criticise him as trying to "set a pace" and during a strike he loses influence with the other workmen. The average workman is ready enough to share in the profits, but not to share in the risks of industrial or commercial enterprises. The workmen have exaggerated ideas of the profits, and not having access to the books are apt to think that they are not getting their full share.

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* Professor of Industrial Engineering, Clarkson Memorial School of Technology.

Some manufacturers share their profits by making an out-and-out gift once a year to all of their employees who do not in any other way share in the profits. Generally these gifts are from 5 to 10% of their annual earnings. Another form of profit-sharing is a pension, and a sick relief plan for the benefit of the workmen and their families. This is eminently proper, for each industry should bear its own burden caused by accident, sickness, disability, and old age.

Most employers do not know what the men and machines are capable of doing. If working on the day's-work plan the men are liable to set an easy pace and the production be far below the amount possible. If a piece-work system is installed the workman is left to devise ways of increasing the output. When the earnings become large the price is cut and the usual dissatisfaction and trouble ensue.

The greatest gain in securing the maximum efficiency in manufacturing can be obtained by conserving the energy of the workmen. This can be done by investigating and studying all the operations performed by the workman, in designing and arranging the tools, machines, and appliances; and in planning the method of doing the work that the workman may produce the greatest amount of output with the least expenditure of effort. This can be secured only by the hearty co-operation of the employer in providing the best of everything wherewith to do the work, and by the workman in using such to the best advantage.

Much has been done by several engineers who have made a systematic and analytical study of each and every motion and operation required to produce a given result, and who have devised means and methods to produce the best and quickest results at the least cost. In Mr. F. W. Taylor's paper, "The Art of Cutting Metals," before the American Society of Mechanical Engineers, the topics such as developing a high-speed steel, determining the proper shape of the cutting tools, and deciding about speeds, feeds, etc., were but incidentals to the study and development of the larger problem. Mr. Taylor's method involved a study of the various operations of a job and in timing these operations; then in changing the conditions in accordance with his time studies, until the minimum time in which the best worker could perform them was determined; and finally in compelling all the workers to conform to the methods of the most skilful operator, and to equal his time, by means of bonuses and penalties.

Every operation, for instance, is made up of a series of motions on the part of the worker. A careful study of these motions will eliminate all the useless movements of both man and material. This will give a set of standard operations to be followed thereafter.

It is thus seen to be a large problem to secure maximum efficiency in manufacturing. It involves providing the proper tools, appliances, and surroundings, and what may be considered the most important of all, namely, the employment of workmen of the proper physical and mental constitution to carry out to the letter the instruction given them for making the standard motions.

The average employer thinks that this is too large a problem to be studied seriously. He thinks it impracticable of execution. In this, however, he is very much mistaken. A series of articles by Mr. Frank B. Gilbreth, in "Industrial Engineering," shows how the adaptation of the standard motions to the trade of bricklaying has increased the efficiency of the men so that they can lay many more brick per hour and earn much more money per day, and to such an extent that for men working under the old methods there is hardly any comparison possible.

Mr. Taylor has worked out his system in some of the largest and most successful shops in the country. Mr. Gilbreth is likewise successful as a contractor, and his men all work according to the standard motions developed by him. The methods of both of these men have therefore withstood the test of commercial use.

Thus we see that to enable the manufacturer to turn out more and better products, at less cost, more attention must be paid to production engineering. New methods, tools, and facilities are expensive, and will be profitable only when the production is large. The overhead and distributing expenses of any manufacturing establishment are great; therefore, there must be a large output to share this burden in order to keep the cost per unit small. This has a tendency to work along the line of division of labor. The manufacturer becomes a specialist in a few things instead of producing a large line of goods.

It is this tendency towards specialization which has caused so many companies manufacturing similar products to unite their forces. Each factory confines itself to a few lines of work for which it is best fitted. This method eliminates ruinous competition in distribution, reduces the overhead and operating expenses, increases the efficiency of each plant, lessens the cost of production, and secures maximum efficiency in manufacturing and construction.

WHAT OUR GRADUATES ARE DOING

J. H. Caster, '07, is in the Production Dept., Canadian General Electric Co., Peterboro.

Walter Jackson, '07, is with the Ontario Power Co., Niagara Falls, as field engineer on construction and extension of works.

S. B. Iler, '08, is with the Seymour Power and Electric Co., Belleville, Ont.

A. D. Dahl, '08, is chemist with the Don Chemical Co., Midland, Michigan.

P. H. Buchan, '08, is in the Maintenance of Way Department, B. C. Electric Ry. Co., Ltd., Vancouver.

H. F. Shearer, '08, is testing engineer in the power apparatus Dept., Bullock Electric Mfg., Co., Norwood, Ohio.

N. G. Madge, '08, is chief chemist with the Continental Rubber Co., of New York.

F. C. Lewis, '08, is designing and estimating in the Railroad Bridges Dept., of the American Bridge Co., Chicago.

C. B. Langmuir, '09, is sales engineer for Factory Products, Limited, Toronto.

Stan. Stroud, '09, is with the Westinghouse Elect. and Mfg. Co., Pittsburg.

C. G. Titus, '10, is manager of the Bartlett Mines, Gowganda.

R. J. Spry, '10, is metallurgist for the B. C. Copper Co., Greenwood, B. C.

H. C. Bingham, '10, is assistant engineer in City Engineer's Dept., Moose Jaw, Sask.

L. J. Ireland, '07, is superintendent of Midland Construction Co., Ltd., in charge of the Seymour Power and Electric Co's construction work.

G. G. Bell, '05, is with Sawyer and Nuulton, of Portland, Me., as designer in power plants, pulp mills and general engineering projects.

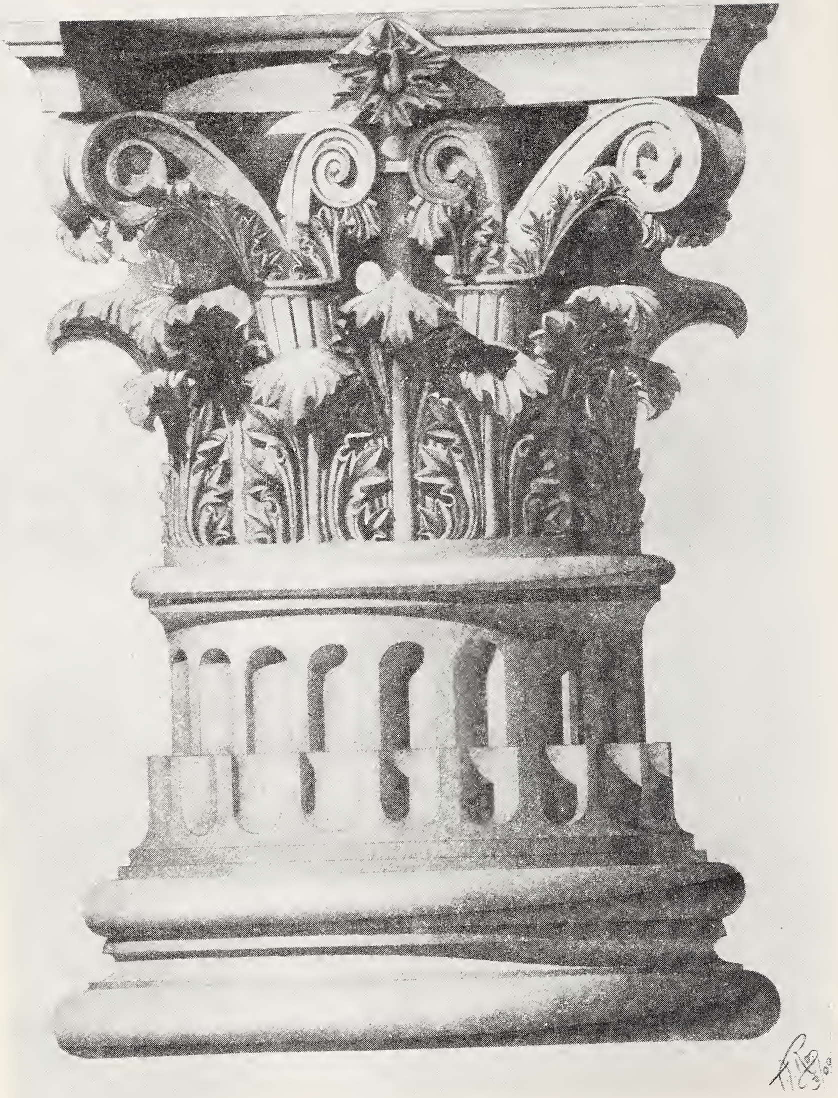
C. J. Harper, '09, is in the employ of the General Electric Co., in Pittsfield, Mass.

E. A. Thompson, '09, is in the electrical department of the office of Smith, Kerry and Chace, Toronto.

L. H. Robinson, '04, is resident engineer for the Transcontinental Railway at Superior Junction, Ontario.

W. A. Begg, '05, has been connected with the Department of Public Works, Saskatchewan, on drainage surveys and road divisions.

E. E. Mullins, '03, has for some time past been mechanicel engineer for the United Fruit Co., operating in Central America and the West Indies. The company owns and operates some 2,000 miles of railroad (about 600 miles of which are in Costa Rica), and 90 steamships. Mr. Mullins has the supervision of repairs and improvements of the mechanical equipment of the railway and steamship lines.



Drawn by T. L. F. Rowe when a First Year Student in the Department of Architecture.

Applied Science

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INCANDESCENT LAMPS.*

M. B. HASTINGS. '11.

Illuminating engineering is simply the engineering method applied to the production, the sale and the use of light. Now, as this paper must be short I have decided to confine my few remarks to the manufacturing and testing of lamps. Hence the title "Incandescent Lamps."

Incandescent lamps, as we are all aware, are divided into four separate and distinct classes, namely, Carbon, with an efficiency of 3.1 w.p.c.; Gem, which is an improved carbon with an efficiency of 2.5 w.p.c.; Tantalum with an efficiency of 2 w.p.c.; and Tungsten with an efficiency of 1.25 w.p.c.

As the Carbon lamp is the first to come into prominence it might be proper to mention a few words with regard to its manufacture. The filaments of the first carbon lamps consisted of strips of woody plants such as bamboo, and vegetable fibres, such as cotton threads, and strips of paper and animal fibres, such as silk, but none of these materials mentioned were found sufficiently uniform in structure, density, electrical resistance and character of surface. The first promising effort to gain uniformity was the effort to parchmentize the outer portion of the cotton threads usually by soaking a limited time in sulphuric acid, but this resulted in a fibre covered with lumps and irregular in section. This objection was overcome by drawing the filament through a series of dies. This process pointed the way to the evidently logical procedure of breaking up the cellular structure entirely, converting it into a viscous compound which could be pressed through an orifice into a coagulent, thus forming a thread of cellulous without structure. Any chemical capable of dissolving cotton may be used, a strong hot solution of zinc chloride being the most common. A solution of gun cotton on acetic acid is used, to some extent, principally in European factories.

The process of dissolving the cotton for carbon filaments in a zinc chloride solution takes the form of a heavy syrup. It is then evacuated at a temperature below the boiling point of water until occluded air and gas are removed. All conditions must be uniformly maintained. After cooling the mass is forced through platinum dies by air pressure, the end of the dies extending about ½ in. into a jar of alcohol, which coagulates the jet of solutions as it emerges from the die. The glass jar containing the alcohol revolves about one revolution in 3 min. which keeps the fibre from tangling as it lays itself down in coils. Inside the glass jar is a hard rubber basket into which the fibre is coiled. One of these baskets will hold enough fibre for 1800 — 2 c.p. 110 volt lamps while it will only hold enough for about 300 — 50 c.p. 50 volt lamps. After standing in alcohol for about 12 hours these fibres are washed, first in a solution of hydrochloric acid water for about 3 hours, then in distilled water for about 2 hours. The idea is to dissolve out all soluble salts from the fibre, leaving only pure carbon with traces of insoluble salts. The latter are afterwards evaporated by the heat of carbonization. If the salts were not almost wholly removed from the fibre the carbon would be porous and brittle. After washing the fibre is wound upon drums about 4 ft. in diameter where it dries. After the fibre is taken from the drum it is wrapped either upon carbon blocks or forms to give the desired shape, and carbonized at a temperature of about 3000 degrees Centigrade. After carbonization the filaments are assorted, cut for length and electrically heated in the presence of paraffine hydro carbon gas. The carbon deposited upon the filament from this gives it a better light radiating surface, also the deposit causes the resistance of the individual carbons to be brought closer together. The amount of deposits is governed exactly by automatic devices. After the carbons have received this coating they are put in stock for factory use. The glass tubing from which the stems containing the platinum leading in wires are made is bought from the glass factory in 3 or 4 foot lengths. This tubing is cut into lengths varying from 1 to 2 in. on a carborundum wheel. These pieces are then placed in an automatic flange rolling machine. From these machines the flanges are taken, assorted and inspected. They are then taken by the stem machine operators, and with the platinum and copper leading in wires together with the anchor wire they are made into stems which after inspection are ready for the clamping department. In this department the stem and filament meet. The operators cement the carbon to the platinum wires by a graphite cement, after which they are baked until the joint will stand soaking in water for 4 or 5 hours without coming loose. We now have the carbon cemented to the platinum leading in wires, ready to be sealed into the bulb. They are then sealed into the bulb and the vacuum is obtained, similar to the process which will be described later in the discussion of the Tungsten lamp.

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*Read before the Engineeriug Society, January 25th, 1911.

Tungsten Lamps.

Within the last few years wires of rare metals have been substituted for the older carbon wires or filaments. Tantalum and Tungsten metals have proven best adaptable for this purpose, and it is the Tungsten lamp especially that this paper is designed to discuss.

Tungsten lamps are manufactured from the ore known as Wolframite, an oxide of manganese, iron and Tungsten (wolfram). Tungsten oxide is now chemically obtained from the crushed ore. Metallic Tungsten, as a powder, is now reduced from the yellow oxide. The paste process by which a large majority of Tungsten lamps is made is as follows: Tungstic acid, as received by the lamp manufacturer, is in the form of a heavy yellow colored powder, and notwithstanding its purity has to undergo a most thorough purification ,and special treatment in order to reduce it to a fine yellowish powder which possesses a slight porosity. This peculiar physical condition is necessary for the successful reduction of the oxide which can be accomplished in several different ways, perhaps most easily by heating to redness in a current of hydrogen. After obtaining this very pure metallic Tungsten the next operation is to mix it with combining material in order to form a plastic mass that may be squirted into the fine threadlike filaments. Some substances can be used for this purpose, but some compound of carbon, oxygen and hydrogen, such as starch, sugar, camphor, etc., is usually employed. The metallic powder when mixed with such combining material has the same consistency and appearance as black putty. It is absolutely smooth and uniform and it is impossible to detect the slightest grain. This paste, as it is called, is placed in a small steel cylinder and forced by a pressure of about 32,000 lbs. per sq. in. through a small diamond die.

The die used in squirting Tungsten filament consists of a suitably mounted diamond of from one-half to one carat in weight, through which a very minute hole has been drilled. In the smaller dies used to-day this hole is only about 0.0014 in. in diameter, which is smaller than an ordinary hair. The hole is drilled in the diamond with a steel needle, ground down so fine that it is as flexible as a hair, and, as can be imagined, the drilling requires considerable time and patience. The stone when drilled is mounted in a steel casting in order to hold it against the enormous pressure used in squirting the filament.

Under such pressure the wearing of the die even by smooth tungsten paste is very rapid. This wearing is a serious matter, as the diameter of the hole, and consequently that of the filament squirted, constantly increases. Moreover, the wearing is not uniform, so that the hole enlarges more rapidly in the direction of one diameter than the other, assuming when worn an elliptical shape. After enough filament for about 1,500 lamps has been squirted it is necessary to have the die rebored, an operation which costs almost as much as the original die. A die cannot be rebored more than twice before it develops cracks or fissures which cause it to break. The next hardest material, sapphire, has been experimented with as a material for these dies, but it is found that such a die is very liable to split, and that it will hardly make 100 lamps before it needs re-drilling.

The filament, after squirting has been likened in character to a filament of putty, that is, while holding its form well and being flexible to some extent, it is liable to break if bent sharply. The filament as squirted is looped back and forth on cards, and after being allowed to dry is cut to form a number of single loops, much as they are seen in the finished lamp.

The next operation is to beat the filaments in an inert gas, or in one chosen to act upon the particular binding material employed, until they reach a red heat which removes any moisture and lighter hydrocarbons that may be present. Each filament is then mounted in a current conducting clips, so that it may be heated by passing an electric current through it. During this final heating or forming, as it is termed, the filament is supported vertically with the loop downward. A very small weight (a few milligrams) is hung in the loop to prevent the filament from being distorted in shape during the heating, which is usually performed in either inert gas or in a very good vacuum, the gas, if used, being again dependent to some extent on the binding material employed. The temperature of the filament is raised gradually, allowing time for the proper reactions and physical changes to take place. During the heating the energy put into the filament rises to about fifteen times that finally required in the lamp, and while some heat is carried away by the forming gas the temperature is undoubtedly much higher than that reached in subsequent operation.

Every trace of binding material is driven out, and the filament when finally brought to a sufficiently high temperature undergoes a sudden and marked contraction in diameter and length as the small semi-molten particles become soft enough to merge into one perfectly homogeneous mass. A piece of such filament under a microscope resembles a drawn wire, and while the surface is not perfectly smooth there is no indication of a granular structure.

At a dull red heat any good tungsten filament is flexible enough to be bent as desired, but when cold is somewhat fragile. For this reason it is a good thing, if possible, to light tungsten lamps while cleaning them, the chance of mechanical breakages being then minimized.

In order to secure a uniform quality of filament, which is absolutely necessary for good lamp making, every step of the entire process of production, even to the smallest detail, must be carried through with exactness. For example, the rate at which the temperature of the filament is raised during the forming process has a most important effect on the final filament structure, and must be carried out with extreme care in order to assure a perfectly uniform run of filament.

After forming the filaments are mounted upon the familiar glass supporting rod as seen in the finished lamp, and the joint between each leg and the supporting and conducting terminal made by electrically welding the filament to the support. This makes a very perfect joint, both electrically and mechanically.

The material used for the hooks and supporting wires affects the performance of the lamp to a considerable extent. Soft copper is used extensively for such supports, also to a somewhat lesser extent, molybdenum, tungsten, tantalum, carbon, platinum or other refractory materials. Soft copper does not alloy with pure tungsten, and moreover occludes but very little gas, so that it makes a very satisfactory form of supporting hook.

The process of producing a high vacuum within the bulb of a tungsten lamp is a great deal more laborious than in the case of the carbon lamp. It is necessary in order to produce a good lamp, and this applies to carbon and other types as well, to remove every trace of gas, not only that actually free at the time of pumping, but that which may later be liberated from anything within the finished bulb. A good lamp vacuum is only possible through the use of very perfect exhausting machinery and through subjecting the entire lamp, filament, glass, and other parts to a proper heat treatment, during the pumping process. The heat treatment tends to drive from the glass walls and other surfaces exposed within the bulb the particles of air which cling to them in a thin film with surprising persistence. A glass bulb pumped while cold will apparently reach a high degree of exhaustion at the end of the pumping process but, if left standing for some time, will be found to possess a very poor vacuum as judged from that required to insure a good lamp performance. This is due to the gradual liberation of particles of air which, during the pumping, cling to the interior surfaces. The filament is heated intensely by passing an electric current through it while on the pump in order to drive from it and from the supporting wires, which are heated by the incandescences of the filament, any occluded gas which may later be freed from these parts and thus spoil to a certain extent the perfect vacuum required for successful operation. During the pumping process the filament temperature must be regulated with great care, the temperature being raised gradually as the bulb becomes evacuated. If, for example, the temperature should be raised too quickly, a thin film of oxide will form on the surface of the filament, which although entirely removed by a further rise in temperature and higher degree of exhaustion, will have been found to have caused a slight change in the character of the surface of the filament, altering thereby its emissivity and radiating properties and injuring its subsequent life performance.

After pumping, the lamps are given an exhaust inspection and aging by burning at a certain percentage over voltage. If, during this inspection, any lamp develops or shows a bluish color or haziness within the bulb it is an indication of imperfect vacuum and the lamp is rejected. The period of burning and per cent. over voltage depends somewhat on the size of the lamp, but in every case has been chosen so that if a lamp is at all likely to develop a poor vacuum it will be disclosed on this inspection.

The glass work required in making the tungsten lamps, is, with the exception of the centre glass stem, practically the same as in the other types of incandescent lamps.

I have now covered in a general way the process of producing the tungsten lamps, and have, I hope, given some slight idea as to the care required in such production. In order to show the performance of the lamps in subsequent service I have at my disposal, loaned by the N. E. L. A., the averaged candle power life curves of 50-40 watt tungsten lamps which were burned on life test at constant voltage corresponding to an initial consumption of 1.25 watts per mean horizontal candle power. The curves in Fig. 1 show the change in candle power, current and efficiency during the period of test, which was stopped at about 1,400 hours. In order to show the life performance, a curve is given showing the per cent. of lamps which were burning at

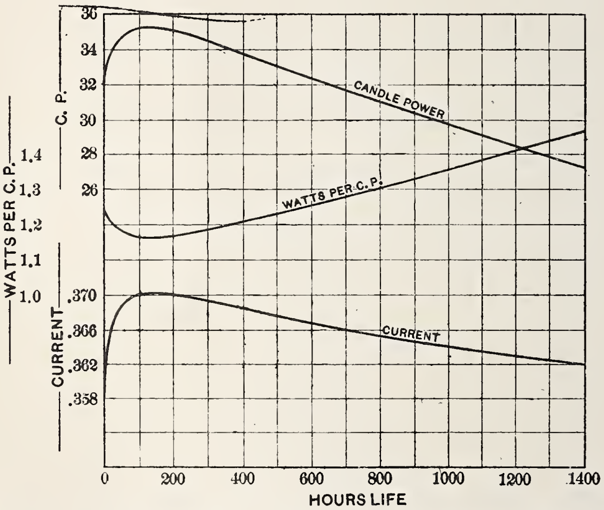


Fig 1 —Characteristic performance of 40-watt tungsten lamps

the end of various periods of time. These curves, Fig. 2, are the average obtained from 80-40 watt tungsten lamps burned under same conditions as the previous test, i.e., at 1.25 w.p.c. About one-half of the lamps were burned in a horizontal position and others in a vertical position, tip downward. These tests were stopped at the end of 2,000 hours.

The change in appearance of the filament during life is rather interesting, and some illustrations showing filaments taken from lamps which had been burned for various lengths of time are shown in Figs. 3 to 23. For comparison, a few tantalum filaments, as well as a few filaments from a gem and from a carbon lamp are shown.

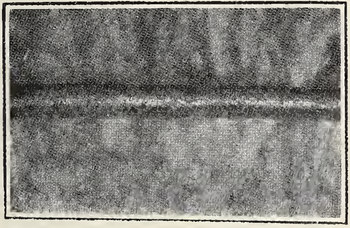


FIG. 3.—Unmounted tungsten filament.

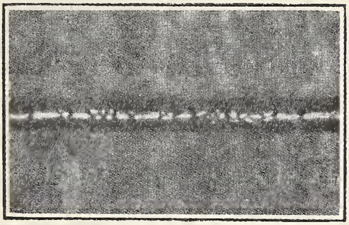


FIG. 4.—25-watt tungsten—400 hr.—alternating current.

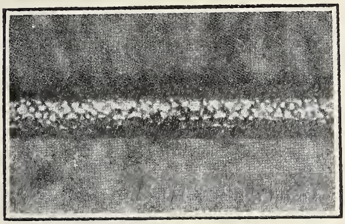


FIG. 5.—40-watt tungsten—180 hr. —alternating current.

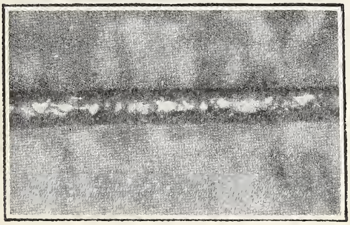


FIG. 6.—25-watt tungsten—1400 hr.—alternating current.

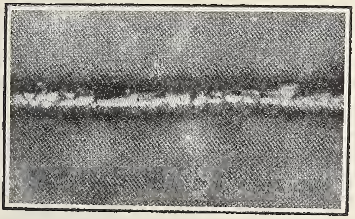


FIG. 7.—40-watt tungsten—898 hr.—alternating current.

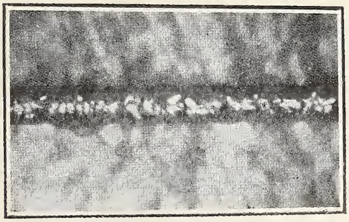


FIG. 8.—40-watt tungsten 2190 hr.—alternating current.

To show the effect of a varying line voltage an increase of 6 per cent. in the voltage of a carbon lamp increases the per cent. candle power as much as an increase of 9 per cent. in voltage of the tungsten lamp. While a tungsten lamp of 10 per cent. under voltage drops in per cent. candle power only as much as a carbon lamp, 7 per cent. below normal. For a circuit where the regulation is poor, the tungsten lamp will be found to give much better satisfaction as far as variation of candle power is concerned than the carbon lamp. The size and filament required in lamps of various candle powers and voltages varies considerably. For 110 volts the size and length varies from a diameter of 0.0013 in. and a total length of 17.4 in. for a 25-watt lamp to a diameter of 0.0060 in., and a total length of 37.56 in. for a 250-watt lamp.

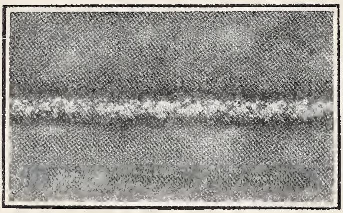


Fig. 9.—40-watt tungsten—300 hr.—direct current.

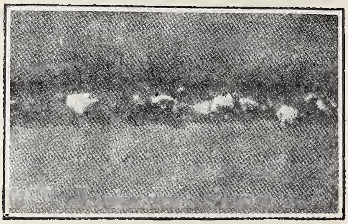


Fig. 10.—40-watt tungsten—3000 hr.—direct current.

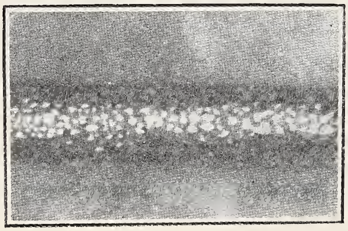


Fig. 11.—100-watt tungsten—1400 hr.—alternating current.

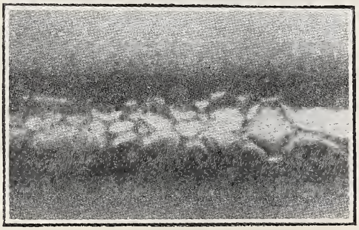


Fig. 12.—250-watt tungsten—200 hr.—alternating current.

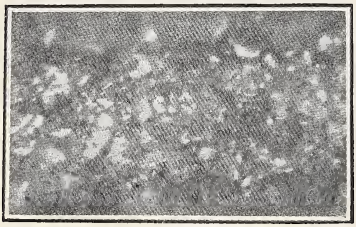


Fig. 13.—Tungsten—street series—2000 hr.

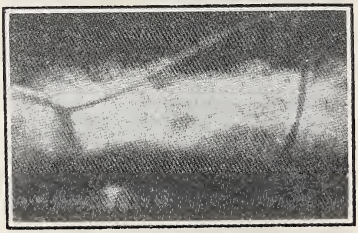


Fig. 14.—Tungsten—street series—2349 hr.

The specific resistance of tungsten is about 46.5 ohms per mil-inch at a temperature corresponding to 1.25 w.p.c., and about 9 per cent. of this figure or 4.19 ohms per mil-inch at ordinary room temperature. This low cold resistance has led to a good deal of discussion as to the value of the starting current obtained upon closing the circuit of a tungsten lamp and its effect upon the filament.

The question is of particular importance when the lamps are turned on and off continuously, as for example, in flashing sign work.

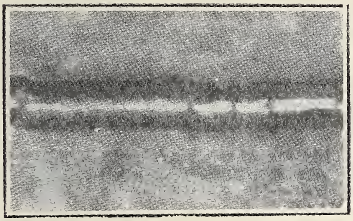


FIG. 15.—80-watt tantalum—800 hr.—alternating current.

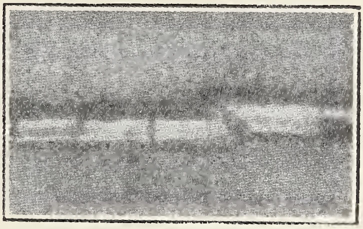


FIG. 16.—80-watt alternating—400 hr.—80-watt alternating current.

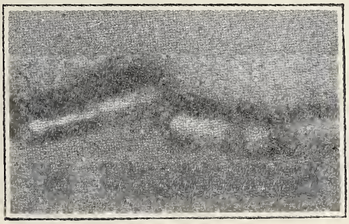


FIG. 17.—40-watt tantalum—800 hr.—alternating current.

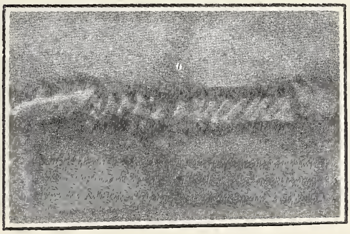


FIG. 18.—80-watt tantalum—948 hr.—alternating current.

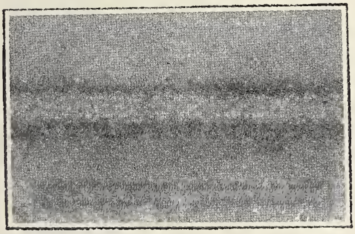


FIG. 19.—80-watt tantalum—60 hr.—direct current.

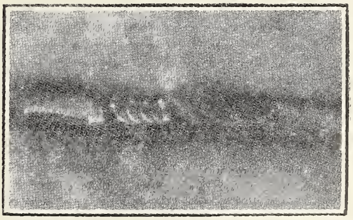


FIG. 20.—80-watt tantalum—455 hr.—direct current.

To most people incandescent lamps are pear-shaped bottles of two or three sizes used for store and residence illumination. As a matter of fact, there are 435 sizes, styles and types of incandescent lamps, and they are used for every conceivable service from street lighting to the illumination of stomach interiors in surgical work. These lamps range from 1-10 to 400 c.p. There are 97 separate sizes and types of bulbs used and 26 sizes and styles of base. There are 22 different types of filaments. If all the different voltages, efficiencies, styles and types are taken into account there are in practice not less than 2,500 distinct lamps.

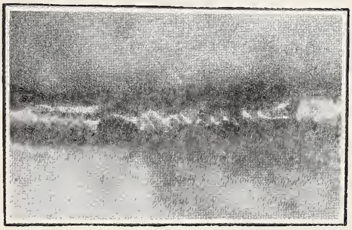


FIG. 21.—80-watt tantalum—1058 hr.—direct current.

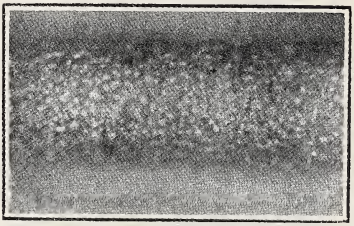


FIG. 22.—Gem—841. hr.

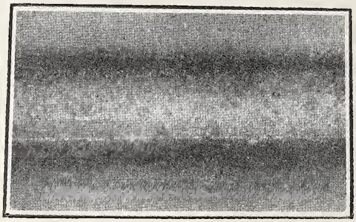


FIG. 23.—Carbon—508 hr.

It may be interesting to explain how characteristics of these lamps are obtained, that is, the data necessary for testing these lamps from a mathematical and scientific standpoint-basis.

The tungsten lamp is measured at a voltage which will make it burn at 1.25 w.p.c., the candle-power, watts, amperes, ohms and volts are plotted and as these readings are from the lamp at its normal condition they are recorded as 100 per cent.

Corresponding readings are taken as the candle-power is lowered to 20 per cent. normal and raised to 150 per cent. of normal. For the normal range of operation these curves can be expressed in the form of parabolic equations, a few of which are given as follows.

Let c = candle-power.
e = efficiency in watts per candle.

V = voltage.
W = watts.

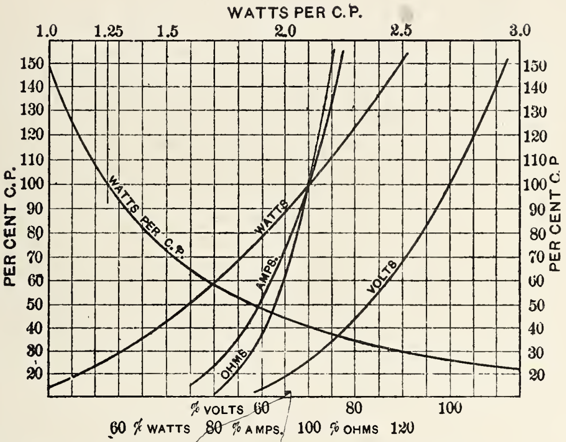


FIG. 24 —Performance of tungsten filament lamp

$$\frac{c_1}{c_2} = \left(\frac{e_2}{e_1}\right)^{a} = \left(\frac{V_1}{V_2}\right)^{b}$$

$$\frac{W_1}{W_2} = \left(\frac{V_1}{V_2}\right)^{d}$$

Values of exponents "a," "b," and "d" are obtained by plotting the corresponding curve on log section paper and measuring the tangent of the angle, which is the value of the exponent required.

These performance curves are of indispensable value in the engineering department in connection with life testing of the lamps sent in by the different factories.

Within the last year the basis of candle-power has changed from the old American candle-power to the International candle-power. The effect of this change from the British unit of 1.6 per cent. in the unit of the Bureau of Standards, which is in general use for electric lighting throughout the country is to raise the candle-power rating and increase slightly the w.p.c. of electric lamps. A 16-candle-power lamp will give 16.26 candles in the new unit, or a 16-candle-power carbon filament lamp burning at 110 volts will give 16 candles on the new basis at 109.69 volts. The change though small is important in the photometry and rating of lamps.

Another recent change is what is known as the 3-voltage plan. The incandescent lamp manufacturers have recently made a radical change in their method of rating these "Mazda" lamps, in order that the lamps could be used with greater economy under those certain conditions where heretofore their cost of operating exceeded that of a less efficient type of lamp and is most valuable in cases where the cost of electrical energy is low. The new method of rating, called "The Three-Voltage Plan," is based upon the fact that for any given set of conditions, depending upon the cost of energy and cost of lamp there is one particular efficiency and life at which it is most economical to operate a given lamp.

Each "Mazda" lamp is labelled with three voltages, two
114
volts apart, as, for example, 112, called top, middle and bottom
110
voltages. This method of rating makes it possible for a customer to select the particular efficiency of lamp he wishes to use by specifying that either the top, middle or bottom voltage, as the case may be, should be the same as that of his lighting circuits.

When burned at top voltage the "Mazda" lamp has the highest efficiency or consumes the least energy for the light produced, and gives life of 1000 hrs. At middle voltage more energy is consumed per candle-power produced and the life is lengthened (due to operation at a lower temperature) to 1300 hrs. At bottom voltage the lamp is operating at the lowest efficiency and gives a life of 1700 hrs. It is obvious that the relative cost of lamp and energy will determine the most economical life and efficiency, since if energy is cheap the saving in energy obtained by operating the lamp at high efficiency is not sufficient to counter-balance the higher resulting renewal expense. On the other hand, if the energy is relatively expensive then it will be desirable to operate the lamp at a high efficiency, since the saving in current at the higher rate will more than pay for the increase in renewal expense.

The efficiency of the different sizes of lamps at top voltage is not the same, since the larger lamps are relatively longer lived than the smaller ones, and, in order to give all sizes a uniform life of 1000 hrs. at top voltage it was necessary to operate the 25-watt. lamp at 1.33 w.p.c., the 40-watt at 1.25 w.p.c., the 60-watt at 100 and 150-watt at 1.20 w.p.c., and the 250-watt and 500-watt at 1.15 w.p.c.

This three-voltage plan was adopted last May by the co-operative companies of the National Electric Lamp Association. Some time prior to this the word "Mazda" was agreed to by the companies forming the National Electric Lamp Association along with others as a word which will accompany the highest efficiency lamp that is made. At the present time the "Mazda" lamp is composed of tungsten filaments or some at present unknown filament which would result in a lamp of higher efficiency than the present tungsten filament lamp, it would be the "Mazda." "Mazda," therefore, is the hall-mark of quality and progress in high efficiency metal filament lamp manufacture, or the seal of the world-wide co-operative effort to produce the best.

A great many people seem to think that illuminating engineering and the different phases of work in connection therewith is narrow, but the "Mazda" lamp and its importance from an invention standpoint shows the broad field there is for the illuminating engineer.

To show its real value, let us consider a steam turbine, electric system and note the great loss in conversion of energy from coal to light.

From Fig. 25, we start with coal containing 100 per cent. energy. Consider boilers working at an efficiency of 70 per cent. we have 70 per cent. going as useful energy to the turbines and 30 per cent. wasted as heat loss. Turbines at an efficiency of 20 per cent., we have 14 per cent. going to generations and 56 per cent. wasted in overcoming mechanical resistance and heat loss. Generations at the efficiency of 93 per cent., we have 13 per cent. going to the distributing system and 3 per cent. wasted. Distributing system 77 per cent. efficient, we have 70 per cent. going to the lamps and 1 per cent. wasted. Lamps 90 per cent. efficient, we have 9 per cent. of the 100 per cent. started with, as radiant heat and light therefore we have only 18 per cent. of what we started with a light when carbon lamps are used. Now let us substitute "Mazda" lamps, and, considering their relative efficiencies as carbon, 3.1 w.p.c. and "Mazda" 1.25 w.p.c., we

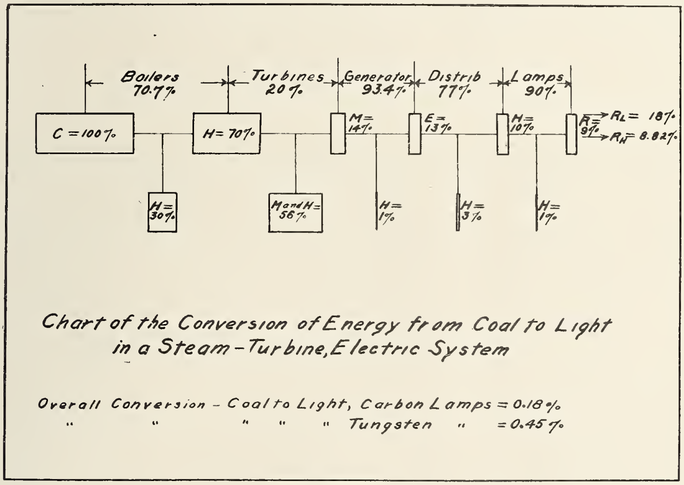


Chart of the Conversion of Energy from Coal to Light in a Steam-Turbine, Electric System

Overall Conversion – Coal to Light, Carbon Lamps = 0.18%
" " " " " Tungsten " = 0.45%

FIG. 25.

would have 45 per cent. instead of 18 per cent. This remarkable triumph in the science of light can be further shown by imagining an almost impossible accomplishment, that is the invention of a turbine working at an efficiency of 50 per cent. Now, if such were the case, 3 per cent. of the original energy would go to the generators instead of 14 per cent. and considering the rest of the system the same as before there would be 32.5 per cent. available for the distributing plant and 25 per cent. would be radiant heat and light; we have 45 per cent. of the original 100 per cent. available for light when carbon lamps are used. Among mechanical engineers it is hardly expected that the existing efficiencies in machines will improve to a very great extent, therefore, the "Mazda" lamp is equivalent to an imaginary turbine of 50 per cent. efficiency and consequently opens a new field in the realms of engineering, and when we look back and find the carbon lamp has been improved from 6.5 w.p.c. to 2.5 w.p.c. in the Gem (which is an improved carbon filament), it is hard for one with a most vivid imagination to forecast its future when it starts at excellent efficiency of 1.25 w.p.c.

The following table shows comparative costs for obtaining 80 candle power from Carbon, Gem, Tantalum and "Mazda" lamps. At the present electric power rates, a large saving is noted in favor of "Mazda" lamps. At a power rate of 10c per kilowatt hour the cost for 80 candle power of "Mazda" light for 1000 hours burning (which includes the lamp cost) is about three sevenths of the actual cost of power alone for equal candle power from carbon lamps of 3.5 w. p. c.

Designation			**Carbon**		**Gem**	**Tantalum**	**Mazda**
Watts per Candle—Actual...			3.5	3.1	2.5	2.0	1.25
Size of Lamps..............			16 c. p.	16 c.p.	40 c. p.	40 c. p.	80 c. p.
No. of Lamps Compared.....			5	5	2	2	1
Total Candle Power.........			80	80	80	80	80
Watts per Lamp............			56.0	49.6	100	80	100.0
Total Watts for 80 c. p......			280	248	200	160	100
Hours Useful Life—Each.....			830	450	460	800	800
Cost of Lamps..............			$ 1.00	$ 1.00	$ 0.70	$ 1.70	$ 1.75
Cost of Renewals, 1000 Hours			1.205	2.22	1.474	2.126	2.188
Cost of Power per K.W.H.	.01	Table of combined cost of Power and Lamp Renewals for 80 c. p. for 1000 Hours	4.005	4.70	3.474	3.726	3.188
	.02		6.805	7.18	5.474	5.326	3.188
	.03		9.605	9.66	7.474	6.926	5.188
	.04		12.405	12.14	9.474	8.526	6.188
	.05		15.205	14.62	11.474	10.126	7.188
	.06		18.005	17.10	13.474	11.726	8.188
	.07		20.805	19.58	15.474	13.326	9.188
	.08		23.605	22.06	15.474	14.926	10.188
	.09		26.405	24.54	19.474	16.526	11.188
	.10		29.205	27.02	21.474	18.126	12.188
	.11		32.005	29.50	23.474	19.726	13.188
	.12		34.805	31.98	25.474	21.326	14.188
	.13		37.605	34.46	27.474	22.926	15.188
	.14		40.405	36.94	29.474	24.526	16.188
	.15		43.205	39.42	31.474	26.126	17.188

The foregoing table shows comparative costs for obtaining 80 candle-power from Carbon, Gem, Tantalum and "Mazda" lamps. At the present electric power rates, a large saving is noted in favor of "Mazda" lamps. At a power rate of 10 cents per kilowatt hour the cost for 80 candle-power of "Mazda" light for 1000 hours' burning (which includes the lamp cost) is about three-sevenths of the actual cost of power alone for equal candle-power from carbon lamps of 3.5 w.p.c.

The chief objection to the tungsten filament lamp is its fragile nature, but this is certain to be overcome when we notice the same objections were made about the carbon lamp about fifteen years ago. I feel safe in predicting a much higher efficiency for the "Mazda" lamp and a perfecting of the strength of the filament to stand any reasonable amount of jar and rough usage.

DRY CELLS.

SAUL DUSHMAN, B.A.

At a meeting of the American Electro-Chemical Society in October, 1909, the following remarks were made by President Baekeland:

"The dry cell, modest as it may appear as a unit, forms the base of a more important industry than most of us imagine. The number of dry cells consumed yearly can be counted by millions, the industry is more important than many electrochemical industries of which we hear much more in our meetings, and read more in print. It so happens, at the same time, that it is one of the subjects on which a very large amount of misinformation is abroad, misinformation sometimes sent out purposely, but most of the time involuntarily through pure ignorance. It is almost impossible to tell beforehand whether a dry cell is good or not, because here everything goes by experience. In fact, I would almost say that the test of a dry cell is to use it for a particular purpose. We are familiar with the phrase 'the test of the pudding is in the eating of it,' but the trouble is that after the eating of the pudding there is none left."

This statement, taken together with the fact that the annual production of dry cells in the United States alone is well over the 50,000,000 mark, shows the importance of a more perfect knowledge of the behavior of dry cells than is at present possessed by the great majority of users.

Construction of Dry Cells.

Probably 80 per cent. of the dry cells made and used are of the so-called No. 6 size, about 6 inches high and 2.5 inches in diameter. A cylindrical zinc container, insulated externally by cardboard, acts as negative pole, while the positive consists of a carbon rod or plate. The zinc can is lined with "an insulating absorbent layer, which serves as a reservoir for electrolyte and as a means of separating the two electrodes. This layer is usually made of a special grade of pulpboard manufactured for the purpose under conditions that prevent the presence of ingredients harmful to the cell." The filling material is packed in between the zinc container and the carbon electrode. A fairly typical filling-mixture has the following composition:

10 parts manganese dioxide (MnO_2),
10 parts carbon or graphite,
2 parts sal ammoniac (NH_4Cl),
1 part zinc chloride ($ZnCl_2$).

Water is added to make a heavy paste and to produce the requisite electrolyte.

Chemical Reactions.

When the cell is discharging the solution of $ZnCl_2$ and NH_4Cl is decomposed by the current; the chlorine liberated at the anode attacks the zinc and forms more $ZnCl_2$, while the hydrogen gas which would otherwise dissolve in the carbon and produce a back e.m.f. is "depolarized" by the MnO_2. The latter is reduced in this process to a manganous salt. The increase in the total amount of $ZnCl_2$ in the cell as well as the decrease in available MnO_2 lead to a gradual diminution in the electromotive force of the cell. The addition of the $ZnCl_2$ to the filling mixture might appear, therefore, to be a questionable procedure. Nevertheless, it has been stated that this addition is necessary.

As the rate of the chemical reactions at the electrodes is always proportional to the rate at which current is taken out of the cell (Faraday's Law) it is readily seen that fresh chemicals must continually replace those used up at the immediate surfaces of the electrodes.

If current is drawn out of the cell at a rate greater than that at which the fresh chemicals can diffuse in towards the electrodes, the electromotive force begins to drop very rapidly, and the cell is said to be "polarized." It follows that the larger the surface of the zinc and the more finely pulverized the manganese-dioxide carbon mixture, the greater the current that may be taken out of the cell without polarizing it. Furthermore, the more homogeneous the mixture, the more rapidly the cell will recover from the effects of heavy currents.

Voltage and Capacity.

The open-circuit voltage varies in different types from 1.5 to 1.6 volts, and is on the average 1.56 volts. The electrical energy output varies greatly with the manner in which the cell is used. When short-circuited an average cell will give from 18 to 25 amperes, falling at the end of one hour to 10 amps. at about 0.5 volt. It is, however, a serious mistake to consider this short-circuit current a measure of the value of a cell. As a matter of fact it often happens that cells which give a high short-circuit current fail badly when tested by the standard of service-capacity, that is, by the number of ampere-hours delivered when the cell is discharged through a resistance of 16 ohms. The following table, taken from Ordway's paper, illustrates this point:

TABLE I.

Short-circuit Current and Service Capacity of Dry Cells.

Brand of Cell.	Short-circuit Current.	Service Capacity.
A	33.0	24.0
B	29.5	46.0
D	24.5	33.5
G	22.5	40.0
J	20.9	18.2
L	20.2	36.0
Q	19.2	38.6
S	18.2	27.1
W	9.7	16.0

An important fact about dry cells is that the service-capacity, as well as the short-circuit current, drops even when the cell is standing on open circuit. This drop in the short-circuit current is known as the "shelf-life" in the trade, and although in itself the short-circuit current may be of no value as a measure of the efficiency of the cell, yet a considerable variation in this current given by an old cell and that given by a new cell is a sure indication of a serious fault in the mechanical construction of the cell.

The energy output of a dry cell depends upon the conditions under which the cell is discharged. The discharge may be either continuous or intermittent, and in the usual case it occurs through a constant resistance. The following table, also taken from Ordway's comprehensive paper, represents typical results obtained at the Research Laboratory of the National Carbon Co., Cleveland:

TABLE II.

Watt Hours from No. 6 Dry Cells Discharged Continuously.

End Point in Volts.	Resistance used in Ohms.						
	2	4	8	16	24	32	40
1.2	3.7	4.3	8.1	15.2	18.8	21.7	23.8
1.0	6.7	13.0	16.5	26.9	33.4	39.8	42.0
0.8	9.7	16.3	21.5	32.8	40.3	44.6	50.6
0.6	12.5	19.4	26.6	48.9	49.5	52.7	53.2
0.4	15.4	27.3	39.1	52.6	54.3	58.2	54.8
0.2	19.8	32.6	41.5	53.3	55.2	59.3	57.1

F. H. Loveridge gives the following values of the energy output of dry cells discharged to 0.5 volt:

With 1 ohm	7 watt hours
With 2 ohms	8 watt hours
With 4 ohms	14 watt hours
With 6 ohms	21 watt hours
With 10 ohms	24 watt hours

When discharged intermittently through the same resistances, the cell gives a longer actual service as long as the voltage does not diminish to less than one-third its original value. After this stage is attained the cell can be operated more efficiently on a continuous discharge.

C. F. Burgess carried out a large number of tests with dry cells obtained from eleven different manufacturers. The number of watt hours delivered by the cells on intermittent service varied from 58.4 to 3.3, and the initial resistance from 0.68 to 0.17 ohm. Burgess states that a good dry cell, when used on intermittent service should deliver 2.27 watt hours per cubic inch contents, and should have a resistance not greater than 0.3 ohm.

The Effect of Temperature.

While the effect of increased temperature on the electromotive force of a dry cell is only slight, the effect on the shelf life is very deleterious. Cells which initially give a short-circuited current of 20 amperes will indicate a current of less than 1 ampere when stored for several months at a temperature of 50° C, while the same cells stored for an equal length of time at ordinary temperature will indicate 18 or 19 amperes. This accounts for the advice of manufacturers that dealers and users store their cells in a cool place.

"The service capacity of dry cells may be either increased or decreased by raising the temperature according to the conditions under which the cells are tested. In general, more service of a severe nature will be obtained if the cells be moderately warmed, while with very light service it is advantageous to keep the cells cool. It is dangerous, under any circumstances, to use dry cells at temperature much above 50°C."

Testing of Dry Cells.

The object of a test is to determine the value of any piece of apparatus or material for a certain specific purpose. Such a test may be either comparative or absolute. In the case of the dry cell the first test to be applied was the measurement of the short-circuit current. At the best this could only be a comparative test; but, as pointed out above, the conclusions to be drawn from it are useless as regards the service capacity. The continuous resistance test was therefore tried next. It was soon found, however, that here again the conclusions of such tests were not applicable to conditions in actual practice. While one cell may be superior to another when discharged continuously, yet the reverse may be the case when both cells are tried on the same ignition arrangement. Or two cells may show equal energy output on continuous discharge, but be unequally efficient when used on telephone service. Now the question which obviously interests the consumer is not the amount of energy which the cell is capable of delivering under certain standard conditions, but **the actual hours of service that he may expect to obtain when operating a definite piece of apparatus under definite conditions with the given cell.** The conclusion, therefore, at which both manufacturers and consumers have arrived is to devise tests that shall duplicate as nearly as possible the conditions under which the cells are to be used, thus making it possible to obtain data by which the cells can be rated for a given service.

As the two main uses of dry cells are for telephone and ignition service, we shall briefly review the nature of the tests which have been elaborated to determine the value of a dry cell for either purpose.

(1) Telephone Service.

"To represent as nearly as possible average telephone service, two or three dry cells should be connected in series through about 15 ohms for as many periods each day as there are calls on an average telephone, each period being the length of an average telephone conversation, and the cut-off point being taken as the lowest working voltage that will give satisfactory service."

A simple test may be carried out as follows: Three cells in series are discharged through 20 ohms resistance for two minutes per hour, 24 hours per day, until the working voltage (taken just before the end of a contact) decreases to 2.8 volts. The test may be varied by discharging three cells in series through 15 or 20 ohms for four minutes per hour, 10 hours per day, until the same voltage is attained.

(2) Ignition Service.

"In the usual type of ignition apparatus the battery current passes through the primary of an induction coil at the right instant in the engine's cycle, and by means of a vibrator is made to rise and fall very rapidly, thus producing pulsations of very high voltage in the secondary, and a series of sparks at the spark plug which ignites the explosive mixture in the engine cylinder. The primary of the average induction coil has a resistance of about 0.5 ohm, and if the circuit through the coil were to be closed indefinitely the current would rise to from 12 to 16 amperes, depending on the voltage of the battery used. The action of the vibrator is so rapid, however, that the current does not have time to build up to its maximum value, and the actual initial impulse rises to only three or four amperes." Tests in which actual induction coils were used have been found to be useless owing to the fact that it is almost impossible to keep the coil in permanent adjustment. The following is given by Ordway as a standard test for ignition-cells: "Six cells in series are discharged through 16 ohms resistance for two hours per day, one hour in the morning and one hour in the afternoon. About twice a week the cells are short circuited through a half-ohm coil for a few seconds, and the current flowing is noted. When this current flowing, or impulse, reaches four amperes, the battery is removed from the test, and the life of the battery is reported as the hours of service given under the above conditions to four amperes impulse through a half-ohm coil. A modern dry cell of good quality will give 30 hours of service on this test at ordinary room temperature of, say, 22 to 24° Centigrade."

Conclusion.

It is evident from the above remarks that there is no single test which the manufacturer or consumer can apply to a dry cell to indicate quickly and simply its value. Each application requires special standards of its own, and it is not at all reasonable to expect that the same type of cell will fulfil the requirements of different users.

List of References.

J. W. Brown. The Use of Dry Cells on Ignition Service. Trans. Am. Electrochem. Soc., 13, 172-185.

C. F. Burgess and C. Hambuechen. Certain Characteristics of Dry Cells. Trans. Am. Electrochem. Soc., 16, 97-108.

F. H. Loveridge. Dry Cell Tests. Trans. Am. Electrochem. Soc., 16, 109-124.

D. L. Ordway. Some Characteristics of the Modern Dry Cell. Trans. Am. Electrochem. Soc., 17, 341-366. All the passages quoted above are taken from this paper.

C. F. Burgess. Tests of Dry Cells. Electr. World, 39, 156.

ARCHITECTURAL DESIGN.

The illustrations used in this article are intended to represent the work done by the different classes in the Department of Architecture of the Faculty of Applied Science. Some problems are given to illustrate the nature of the requirements, and the wide scope for the students' original ideas.

The department is in the charge of Mr. A. W. McConnell, who is a graduate of this department of the University, being a member of the class of '06. Mr. McConnell has further spent several years studying design in Paris and has brought back with him a thorough knowledge of the methods of teaching design as practised in the Atelier de M. Gromort.

A large number of the leading architects of this and other cities have visited the Department of Architecture during the present session and have expressed unanimously their approval of the work done by the students in this department. Those who are in the position to know, compare favorably the work in Toronto University with that of similar departments of American universities.

Applied Science understands the encouragement that such appreciation has for the students in architecture, and hopes other members of the profession will pay visits of inspection to their studios in the Engineering Building.

Following is a list of problems that are typical of those comprising the course:—

First Year Problems.

I. Survey of Building.

The student is asked to make measurements of a building or part of a building in his regular course of surveying and represent the same in plan, section and elevation in his studio. (See Plates II. and III.)

II. Orders of Architecture.

Arrangement of plates in it, using the various orders of architecture. (See Plates IV. V. and VI.)

Second Year Problems.

I. Porch for City Residence.
(See Plate VII.)

II. A Small Public Library.

The student is asked to make sketch plans in the class-room, and to work out the problem in plan, section and elevation in the studio, developing his original idea. (See Plate VIII.)

Third Year Problems.

I. A Dispensary for Children.

(See Plate IX.)

II. A Railway Station for Suburban Line.

This building is to be erected in a suburb of a large city facing a bridge over a viaduct on a busy thoroughfare. The line passes 25 feet below the street level. The building will not exceed 80 feet frontage.

The following accommodation is required:—

(a) Large hall.
(b) Two ticket offices.
(c) Station master.
(d) Baggage rooms with elevators for both lines.
(e) Newspapers, etc.

(See Plate X.)

III. A Small City Hall.

(See Plate XI.)

IV. Music Hall.

This building is to be erected in a public park in a city of 40,000. The front elevation is not to exceed 80 feet in length. Concerts will be given day and night.

Required—

(a) Vestibule with ticket offices.
(b) Porticos, also to be used as a shelter for the people in the park.
(c) Auditorium with seating space for 400.
(d) Stage for 50 musicians.
(e) Library for music.
(f) Lobby for artists.
(g) W. C., etc.

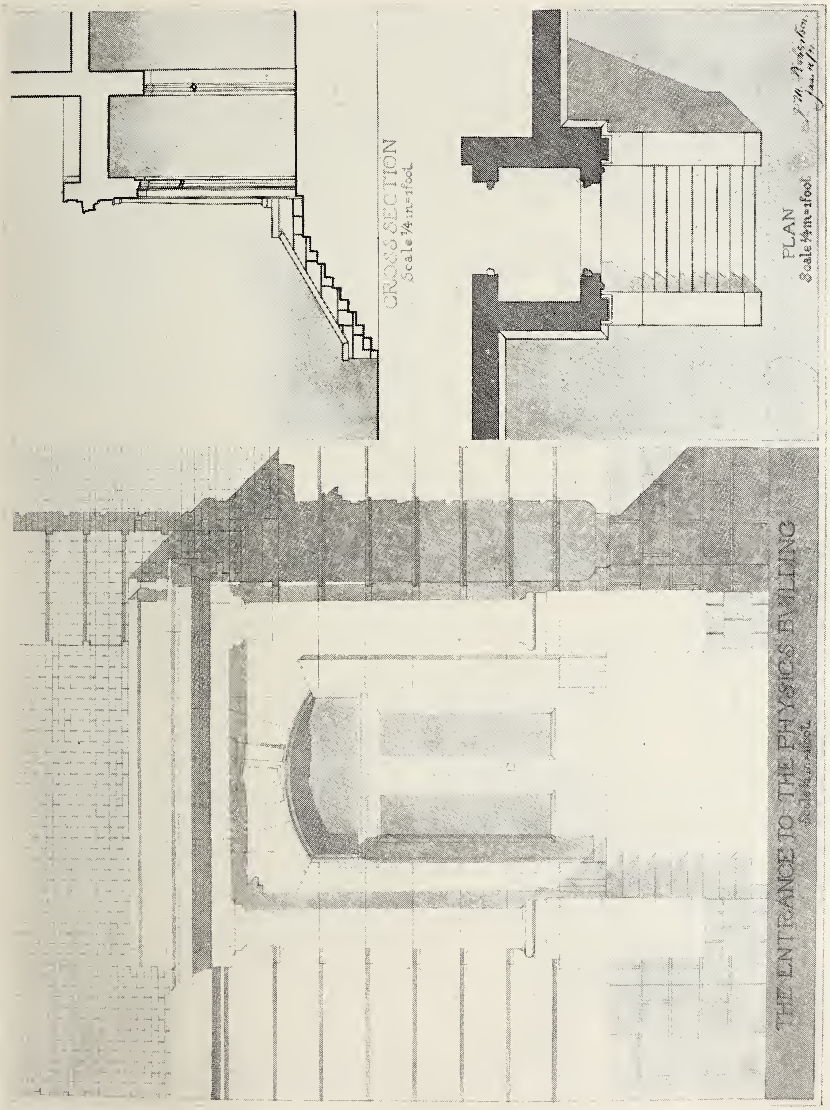


PLATE II.
Measured Drawing by J. M. Robertson.
(See First Year Problem II.)

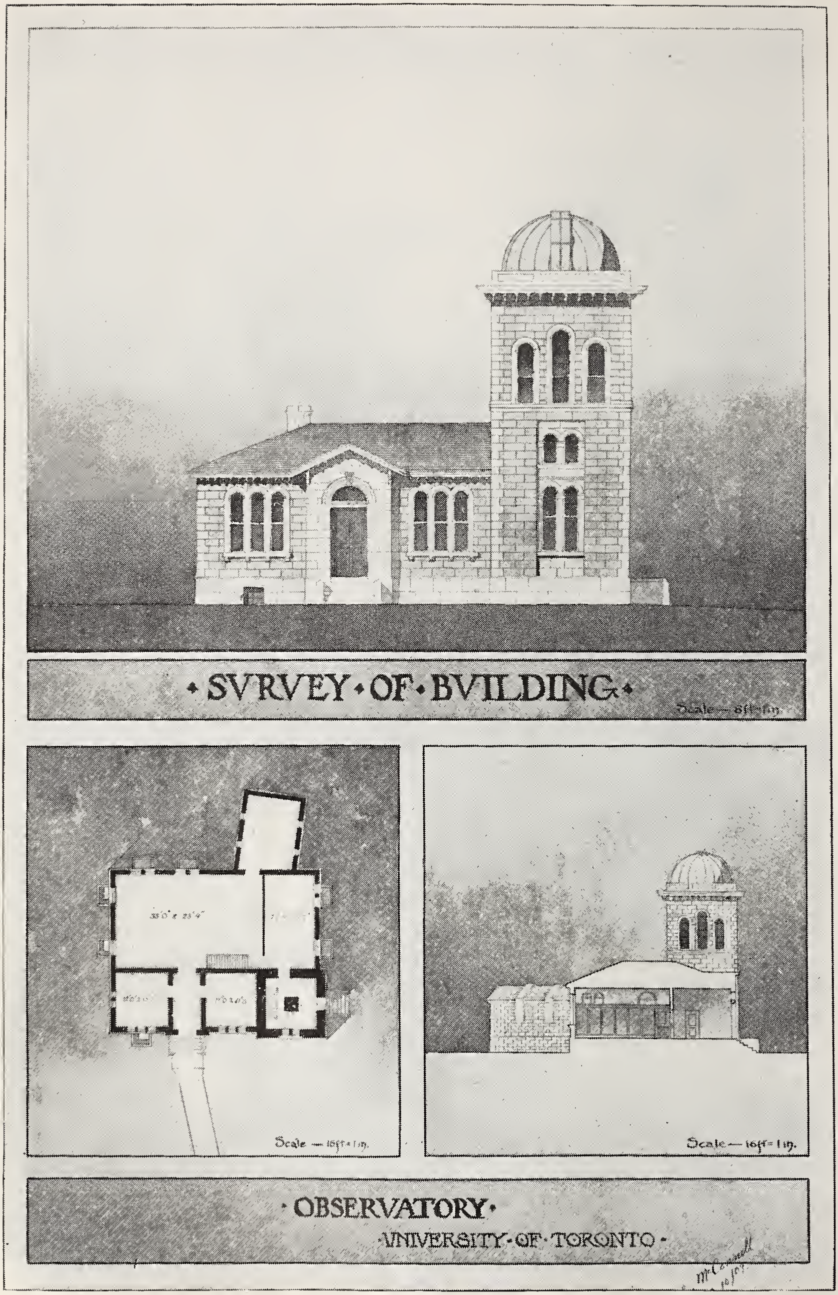


PLATE III.
Measured Drawing by R. S. McConnell, '13.
(See First Year Problem I.)

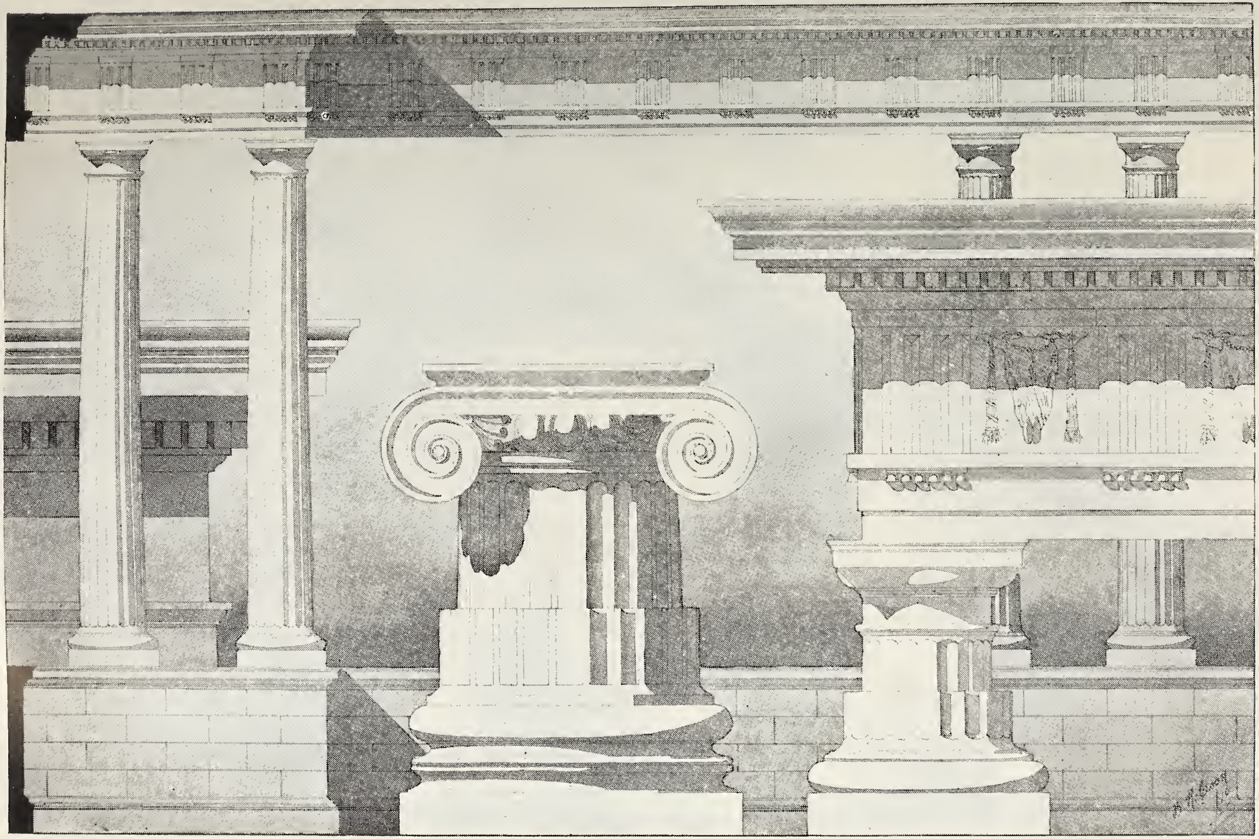


PLATE IV.
Designed by B. R. Coon.
(See First Year Problem II.)

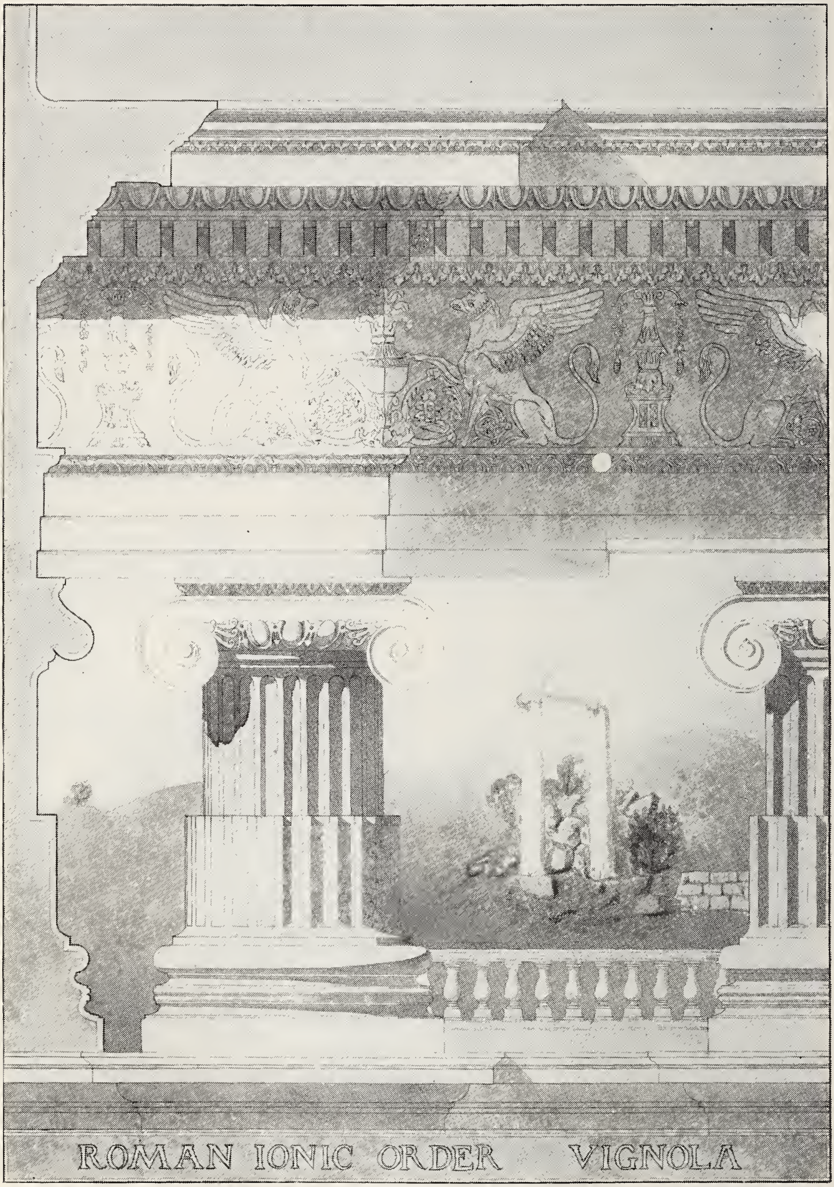


PLATE V.
Designed by R S. McConnell, '13.
(See First Year Problem II.)

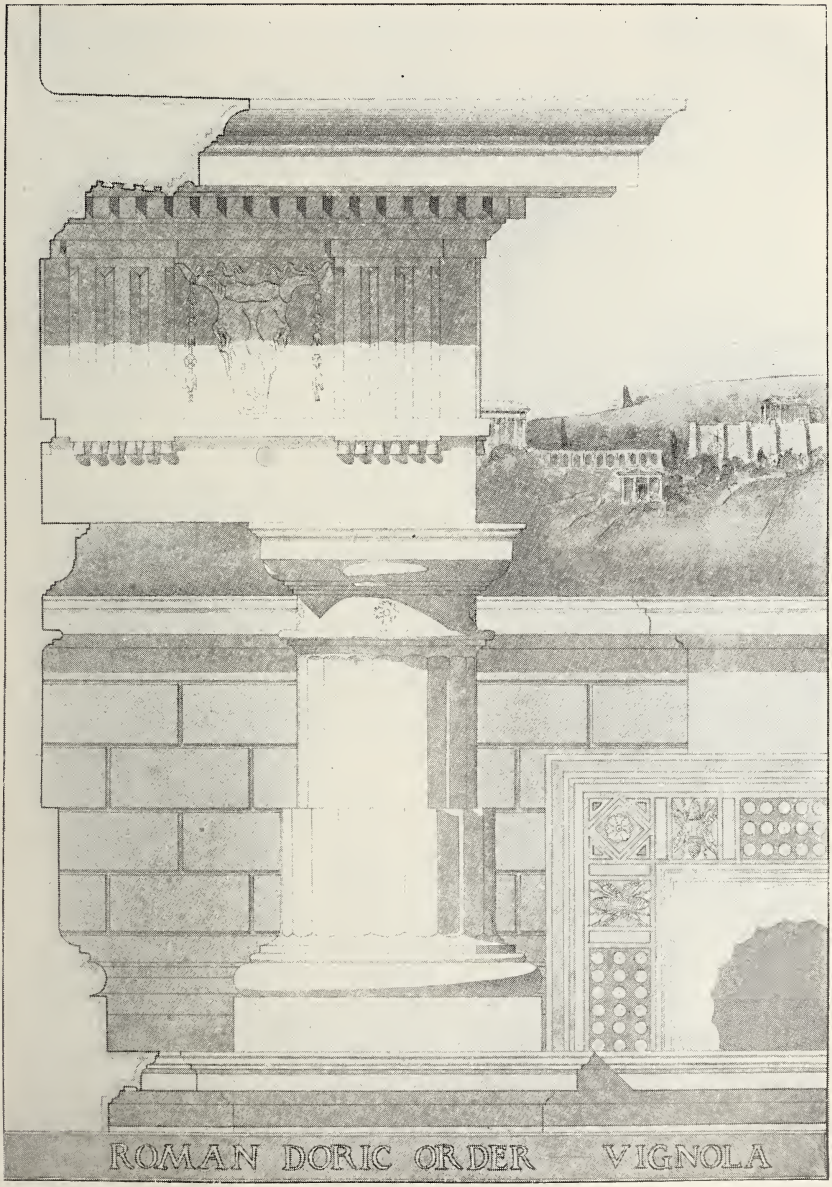
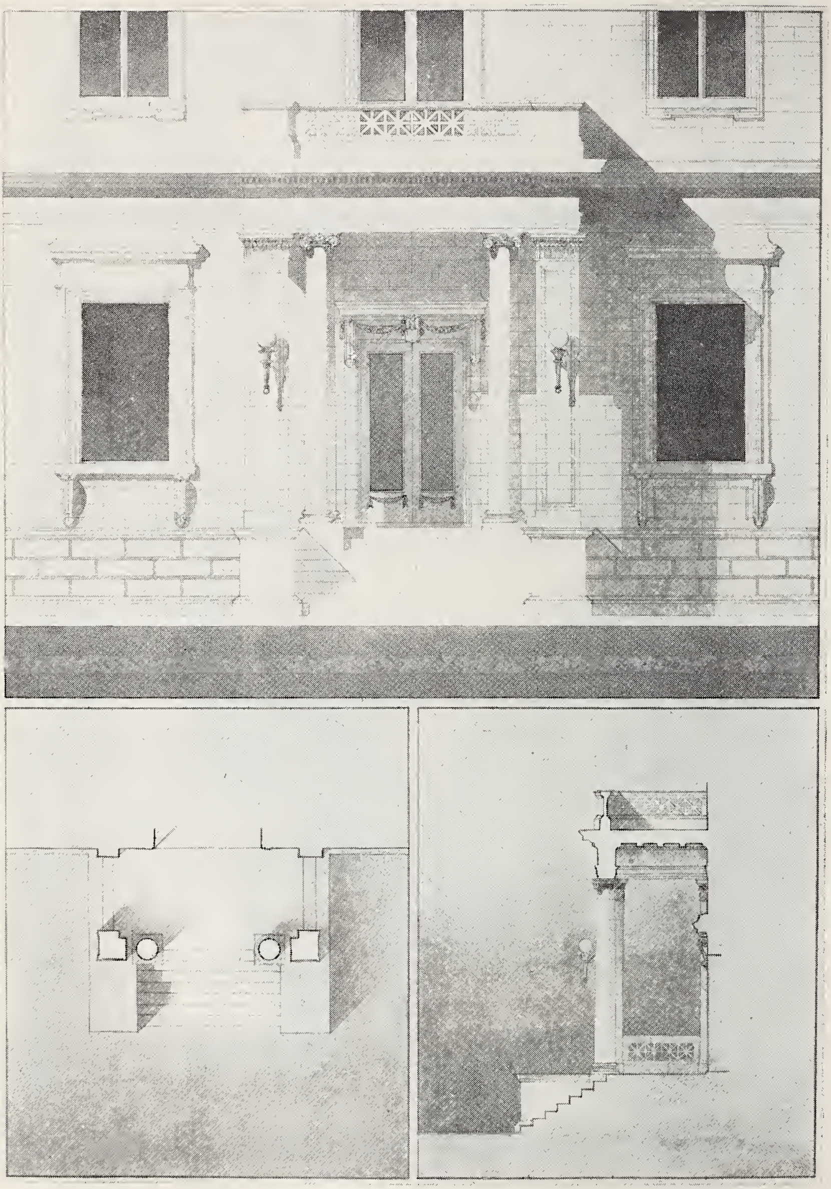
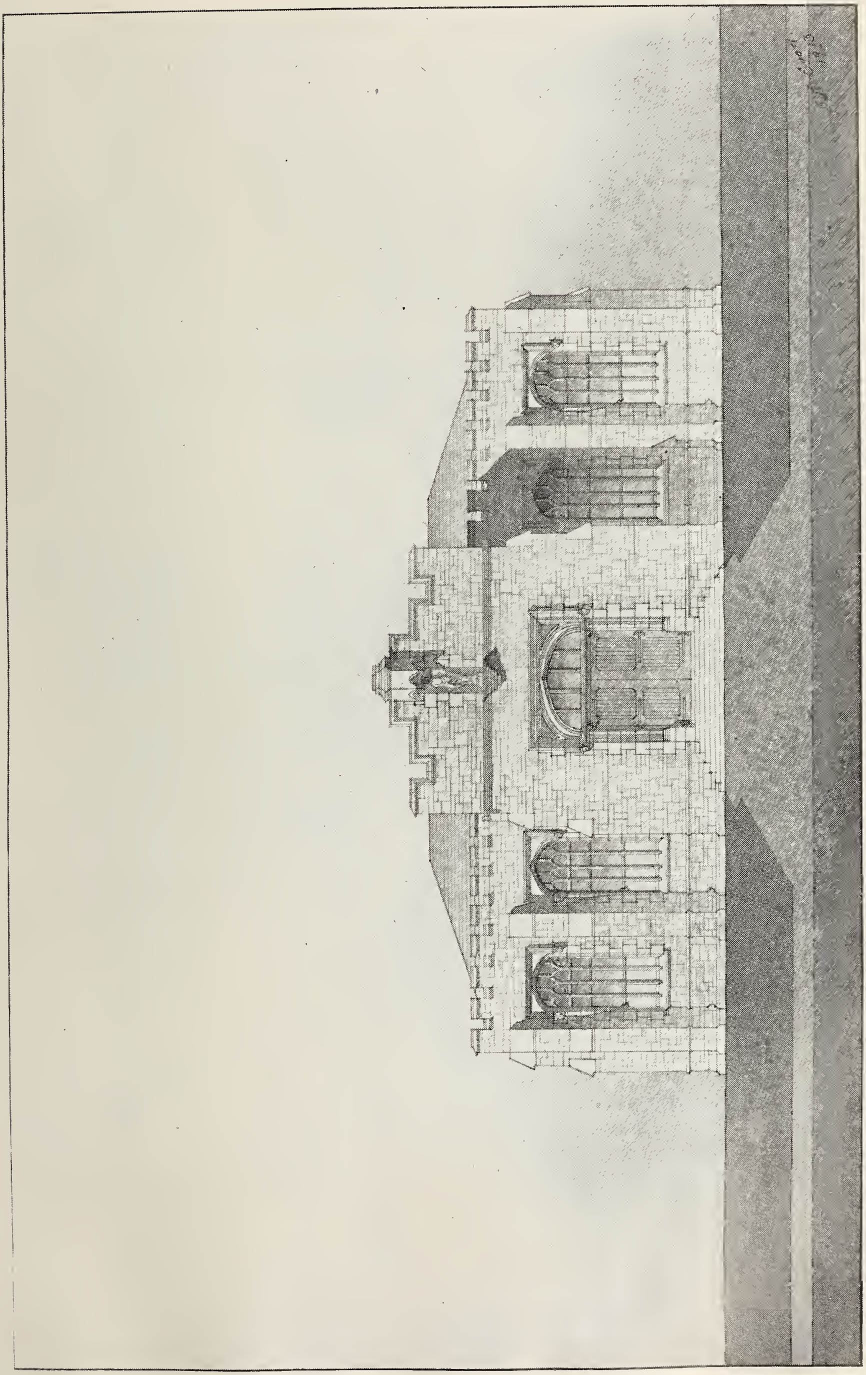


PLATE VI.
Designed by R. S. McConnell, '13.
(See First Year Problem II.)



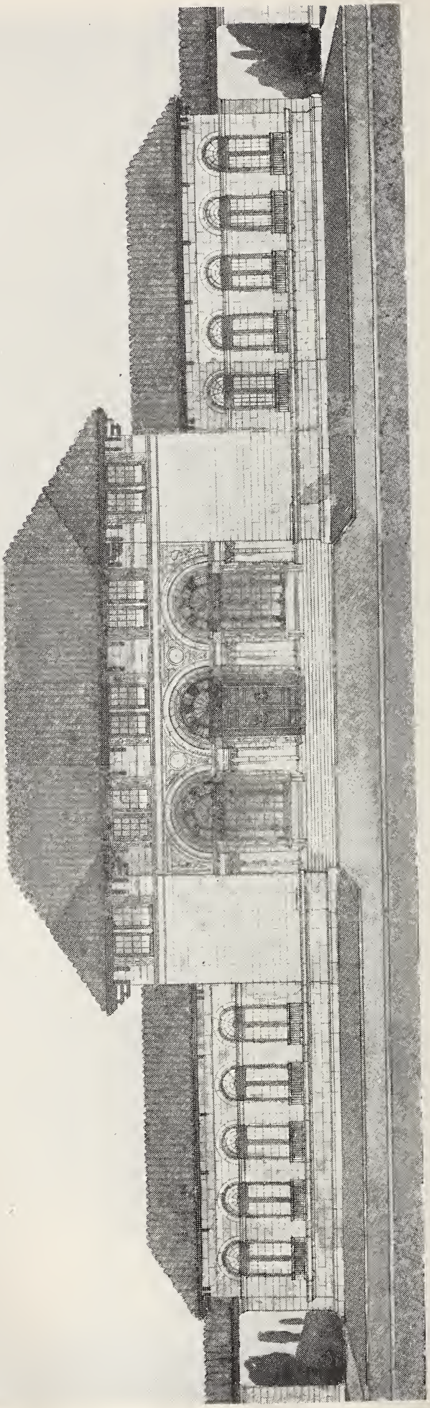
Porch for City Residence.

PLATE VII.
Designed by H. H. Madill, '11.



A Small Public Library.

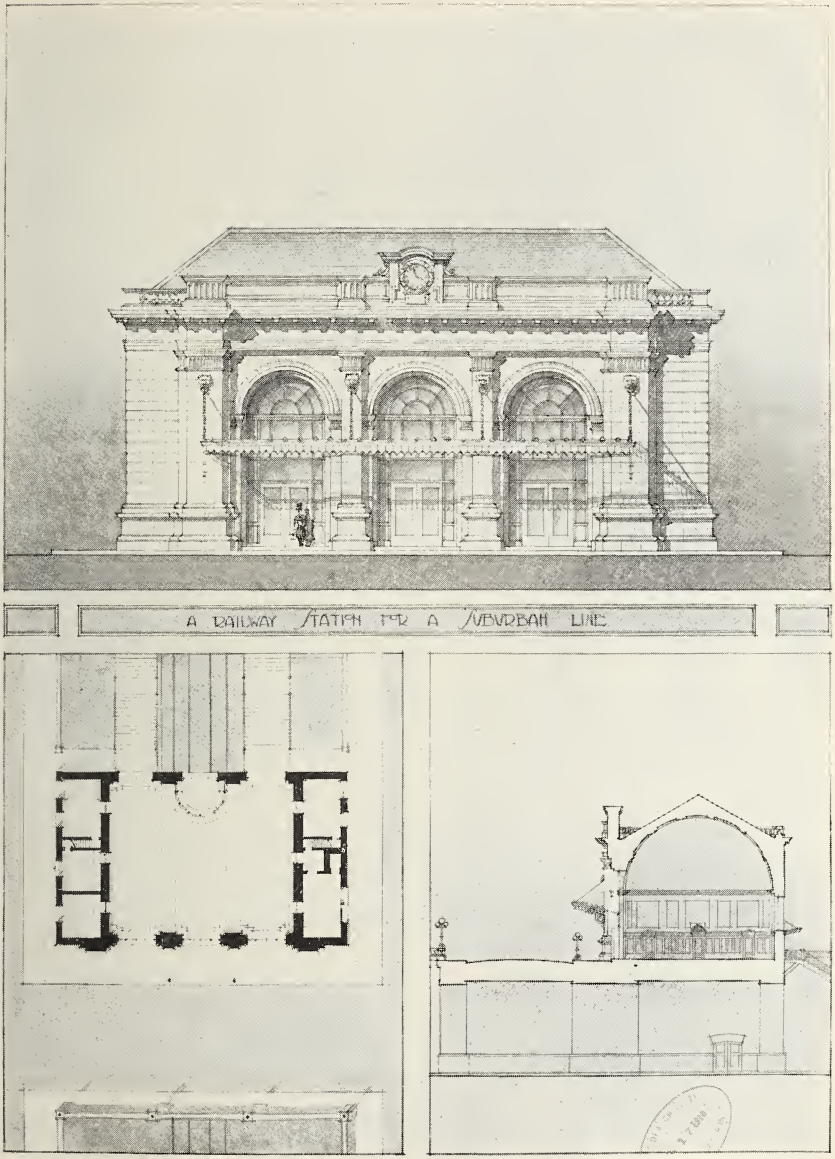
PLATE VIII. Designed by B. R. Coon.
(See Second Year Problem II.)



A Dispensary for Children.

PLATE IX.

Designed by J. B. K. Fisken.

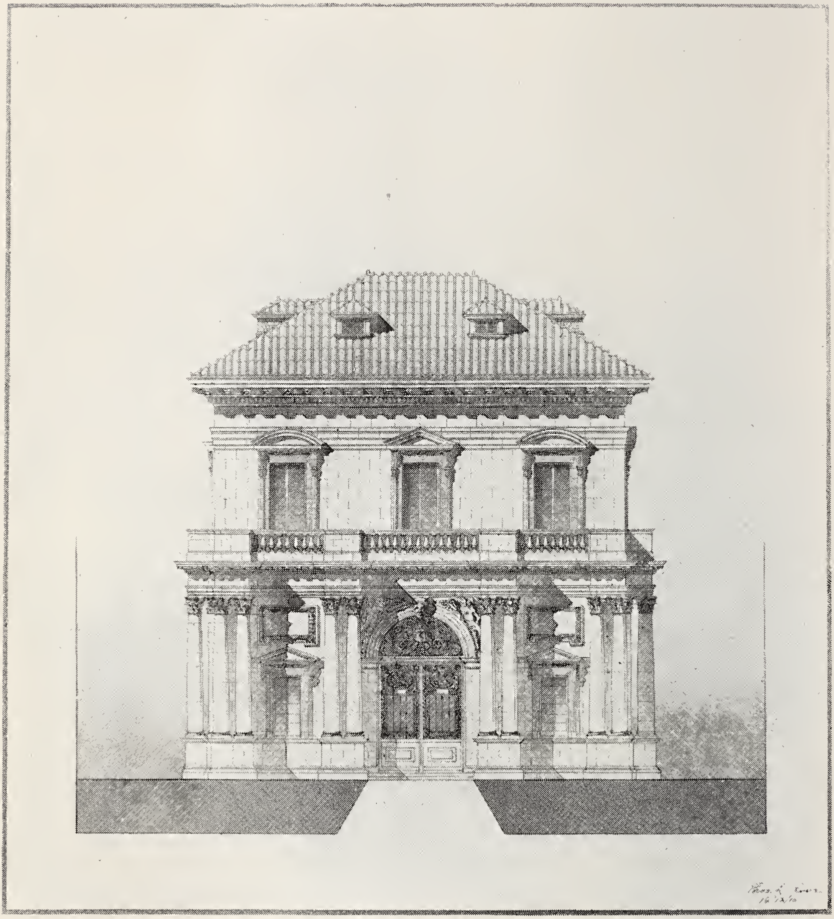


A Railway Station for Suburban Line.

PLATE X.

Designed by H. H. Madill, '11.

(See Third Year Problem II.



A Small City Hall.

PLATE XI.

Designed by T. L. Rowe.

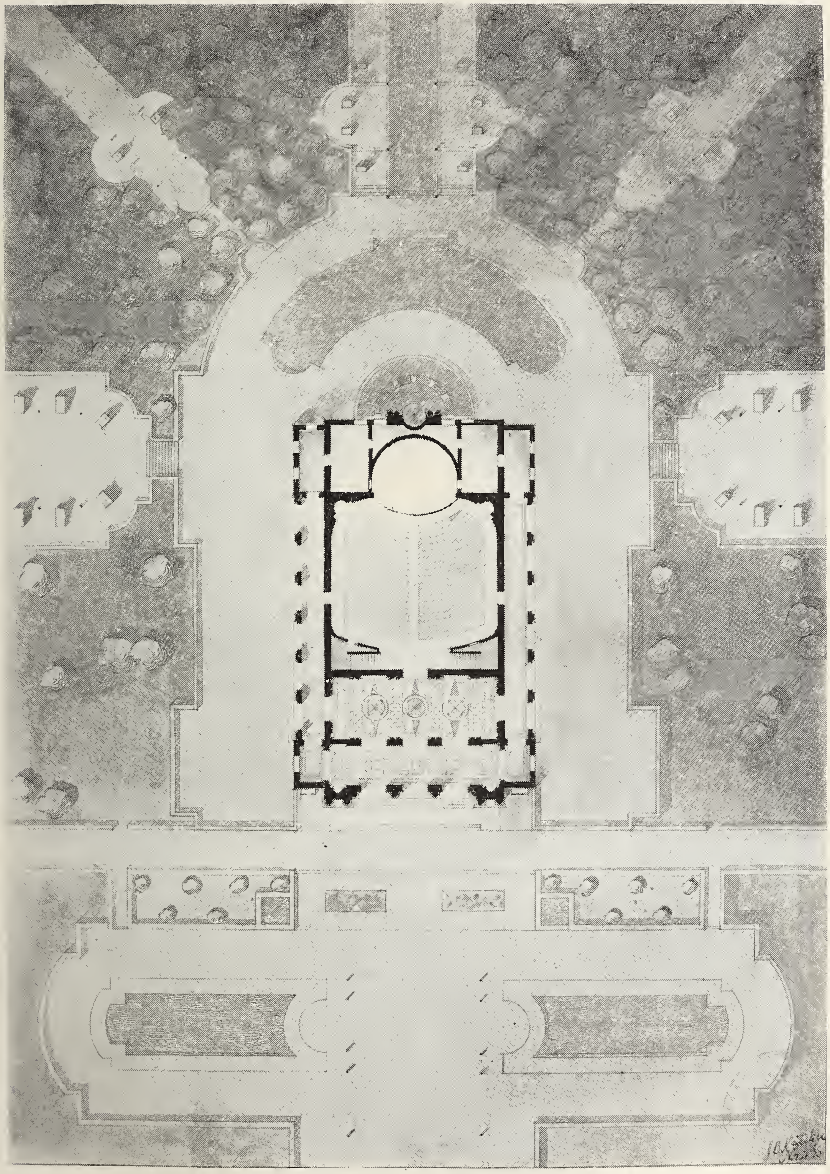
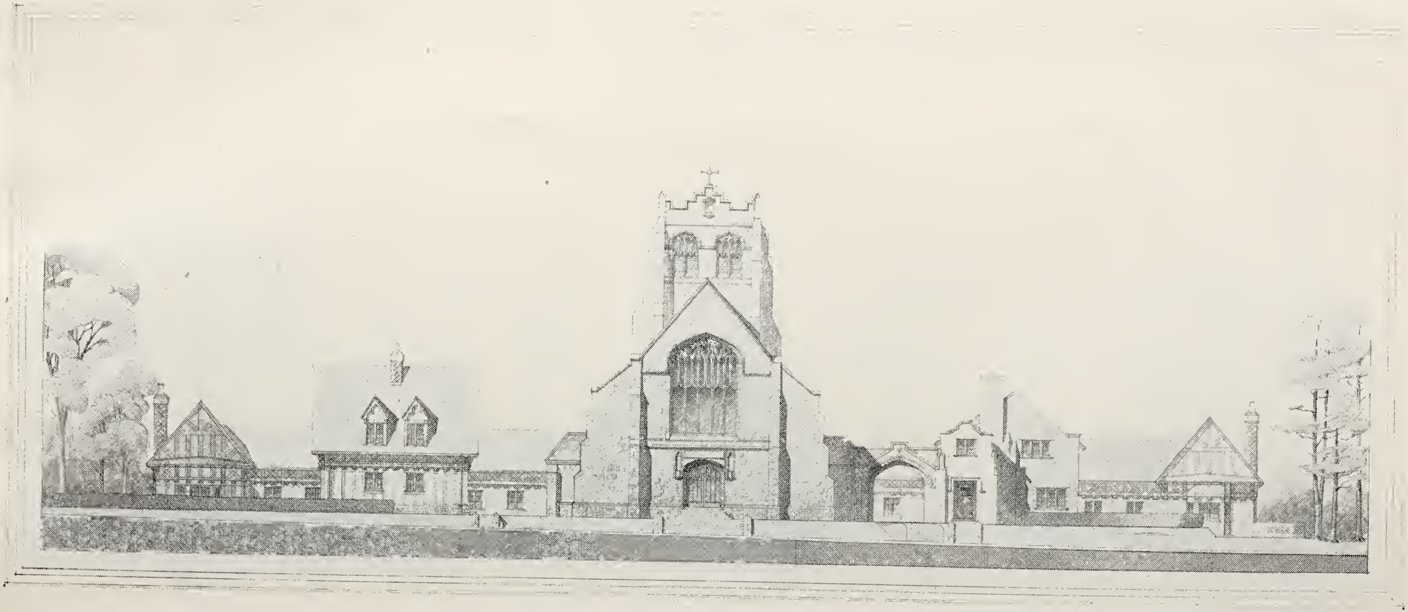


PLATE XII. Music Hall.
Designed by J. B. K. Fisken.
(See Third Year Problem IV.)



A Home of Rest for the Aged Poor, with detached Chapel and Manse.

PLATE XIII.

Designed by H. H. Madill, '11.

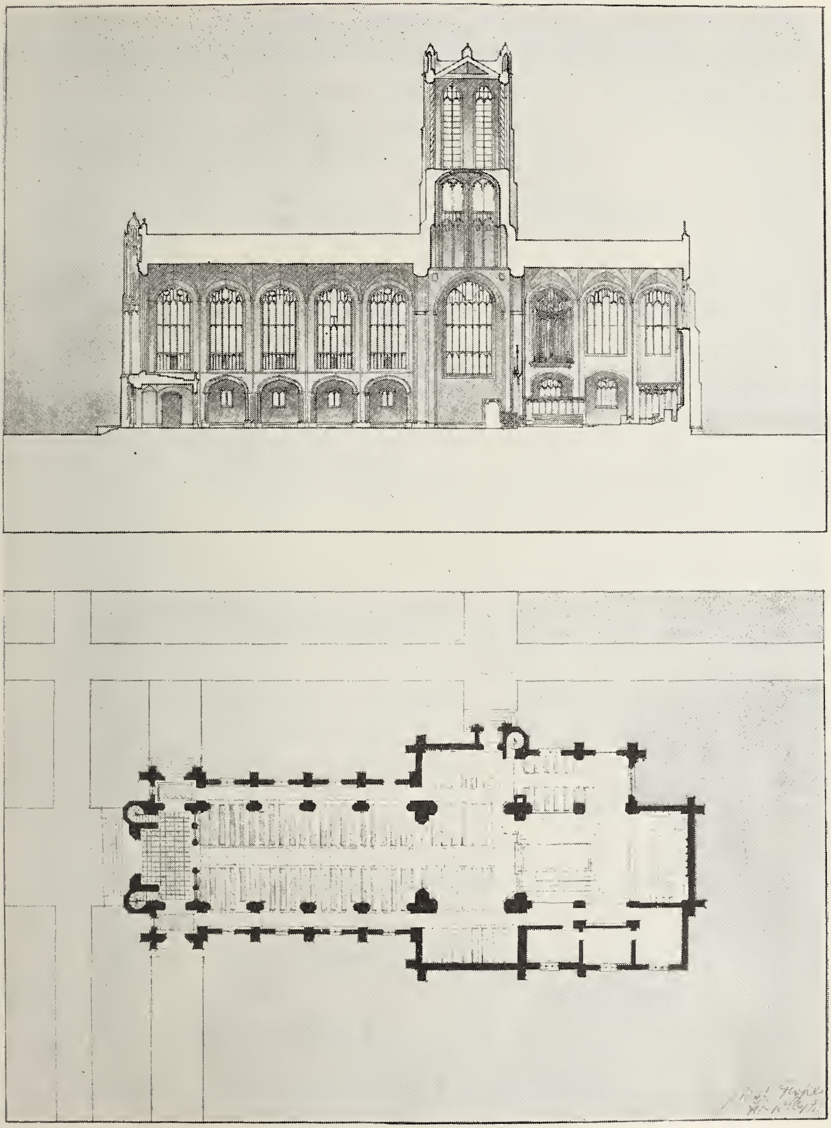


PLATE XIV. A Gothic Church.
Designed by J. B. K. Fisken.

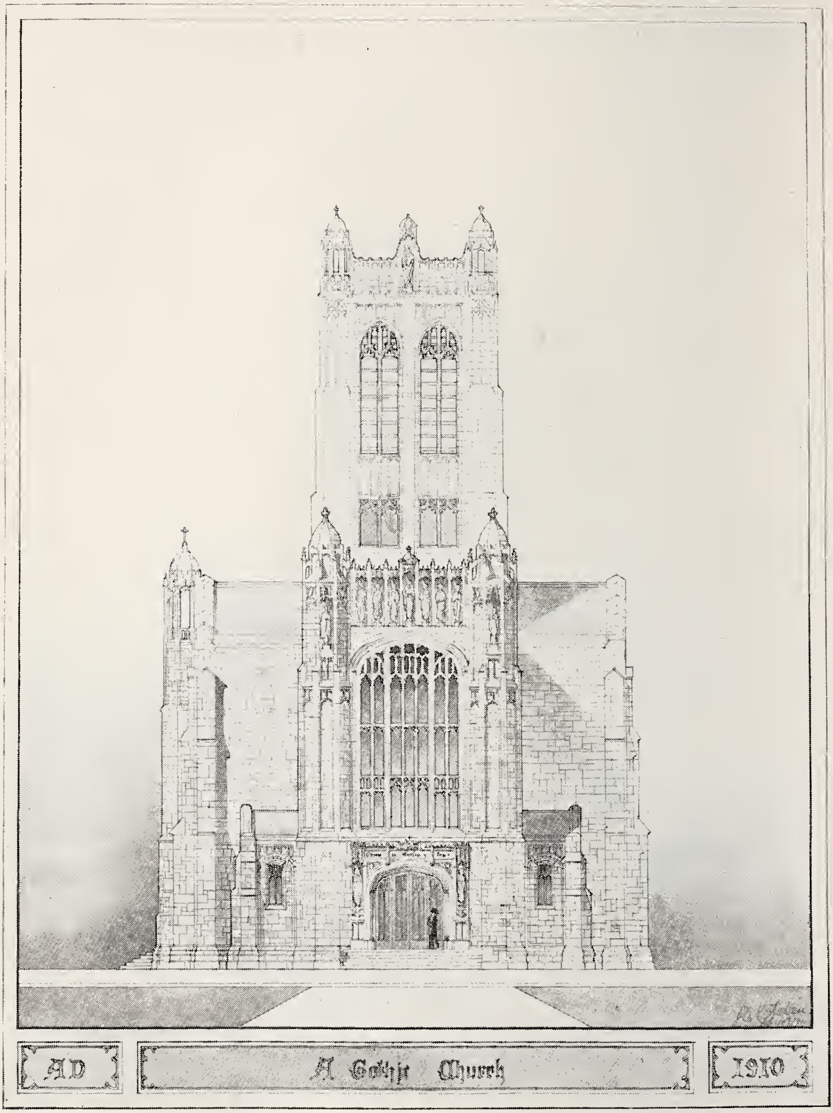


PLATE XV. A Gothic Church.
Designed by J. B. K. Fisken.

THE ENGINEERING SOCIETY DINNER

The twenty-second annual banquet of the Engineering Society has been added to its list of predecessors as a success from every point of view, and the executive upon whose shoulders the responsibility was placed are reaping a reward of praise for their untiring efforts.

To undergraduates the dinner has been a yearly opportunity to assemble as one of the strongest organizations of its kind, to meet the graduates of previous years, and to listen to men who, as statesmen, are at home when in the midst of plans and conceptions for the material betterment of Canada; and who endeavor to impress upon the undergraduates that it is they, as engineers, in whose hands the carrying out of these plans will be placed.

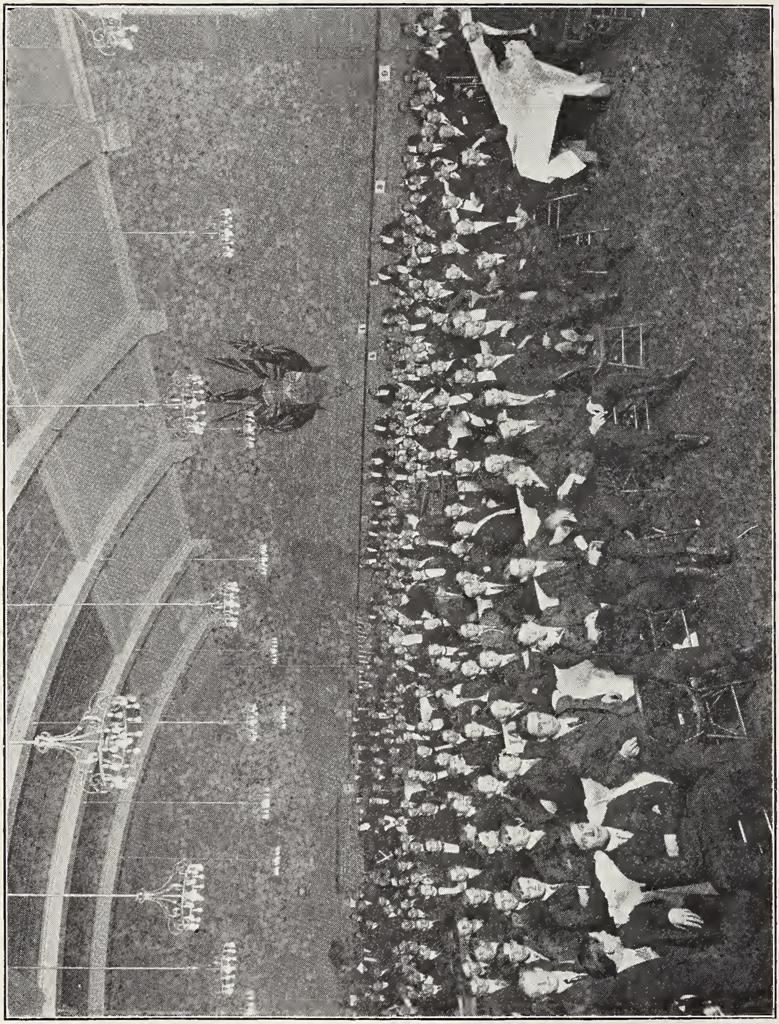
To graduates, the banquet is a reunion, a rendezvous of old classmates and instructors, and the founding of an acquaintance with those who are preparing to assist them in the building of productive transportation and commercial economy, and in the managing of material affairs in general.

To those who come as the guests for the evening, the dinner gives an idea of the magnitude of this Faculty of the University, of the student " esprit de corps " that is so necessary to its advancement, and of the forces behind it all, the forces to which many of the most successful engineers in America claim they owe a great deal and feel proud of, and on which the student to-day relies so much.

What is being accomplished in the Faculty of Applied Science and Engineering has been regrettably unknown to the majority of statesmen, unless they happen to be engineers, or have been in contact with the graduates. But the methods employed, the equipment used, and the needs of both these factors, to operate on the ever-increasing scale cannot be brought to their attention unless they become interested in the profession of engineering in general. The annual banquet of the Engineering Society accomplishes a very great deal toward this end.

Upwards of six hundred were present on the evening of January 19th in Convocation Hall. Mr. A. D. Campbell, the President of the Society, officiated as toastmaster. In welcoming the members of the Toronto Board of Trade as guests of the evening he dwelt briefly upon the fact that some of their interests ran along the same or parallel lines with many of our own future interests. He extended to all, on behalf of the Faculty and its students, an invitation to visit our buildings and equipment, and to study what is here being accomplished for and by young men.

Mr. L. E. Jones, '11, was called upon to propose the toast to "Canada," and coupled with it the names of Dr. Robertson,



The Twenty-second Annual Dinner.

Chairman of the Royal Commission on Technical Education, and Major Leonard, of the Board of Governors. In reply Dr. Robertson spoke as follows:

Dr. Robertson.

Mr. President, Dr. Falconer and Gentlemen,—I thank you, on behalf of the Royal Commission on Industrial Training and Technical Education, for the honor and pleasure of being one of your guests to-night and, for myself, for the honor and privilege of speaking briefly to the students in the Faculty of Applied Science in such a great institution as the University of Toronto.

Canada is becoming a great country, while still a comparatively young country. We older men like to be associated with youth. That helps to keep us young in outlook and in faith. The young in heart, the clear in mind with trained abilities and spirits animated by goodwill, are needed for the upbuilding of Canada. Here you have a good place for training. Teaching is not the whole of training, and telling is only a small part of teaching. The other day in New York I had a talk with two men eminent for their labors and gifts towards the improvement of technical and professional education. Referring to the recent bulletin issued by the Carnegie foundation it was confirmed that the University of Toronto stands in the very front in its physics and engineering departments, and that its splendid equipment was cared for and used with an efficiency not surpassed by any other institution which prepares men for the profession of engineers. Canada is a big place with great possibilities. It needs big men trained to cope with them and make the most of them for the benefit of all the people. The big tasks cannot be undertaken with hope of good results unless men and women of native talent are trained for the work."

In referring to the enormous extent of Canada and its vast, varied and valuable natural resources, Dr. Robertson said that conservation of resources does not mean keeping them out of use. It calls for their development by the application of scientific methods directed by capable men. That makes it possible not merely to pass on to our successors the natural resources unimpaired and undiminished by waste, but actually improved and extended by intelligent management. Competent engineers are needed more and more for all that.

Dr. Robertson gave an outline of the work of the Commission on Industrial Education. Its mission was to enquire, to gather information, and not to propose policies or advocate systems. In its survey of Canada it had already heard the testimony of some thirteen hundred men and women; it had among its witnesses such men as Dr. Falconer, the honored and beloved President of the University, and also men and women who worked at benches and on machines for daily wages. There was agreement in the desire expressed from all sides that Canadians should be industrially efficient; and efficient for all the duties which came to them as workers, as citizens, and as men and women. Trained leaders are no less required than skilful workers. Intelligence, practical ability and goodwill, are needed all through the population, in the ranks with the staff and most of all at "headquarters."

After referring to the production of wealth from natural resources by farming, mining, fishing, lumbering and manufacturing, Dr. Robertson spoke of the essential partnerships which exist between the dieffrent localities and provinces of the Dominion. "We have seen nothing in our survey of this country which indicated that the progress and prosperity of any locality was made to the injury of the others. We are partners as provinces and partners in serving Canada in the various occupations which we follow. Men on the football field strive for the supremacy, for winning in the game. But members of competing teams are not hostile to each other. They are friends and supporters of the game. Team play is the best play for the individual as well as for the team. In the national game of playing for the greatness and goodness of Canada among the nations the same holds good. We must inspire the newcomers, the stream of foreign blood pouring into our citizenship, with the same spirit. They are not only among us, they are of us. Our safety and their welfare are not to be ensured by aloofness or separations or disparagements, but by helping them up to our standards of fair play, by playing the game that way ourselves.

Dr. J. W. Robertson.

Particularly by means of education we must bring them up to our plane and aim higher ourselves. We must teach them to love and serve Canada, and example is here stronger than precept. You young men particularly, who are among the elect in opportunity, as shown by your attendance at this University, must set an example of clean living and clear thinking, and hard work with good will. Thus, you can extend the blessings of your heritage of blood and opportunity for the glory of Canada, and the good of your fellow-citizens throughout the whole land."

Major Leonard spoke briefly, basing his remarks upon the amazing advance Canada has made during the past decade. He emphasized Dr. Robertson's advice to undergraduates to endeavor to realize the responsibility that rested with them.

"Our engineers must be trained for the work they must do. They must be trained to meet the problems of transportation, for instance. We already have great railroads and canals. We are building greater railroads and greater canals.

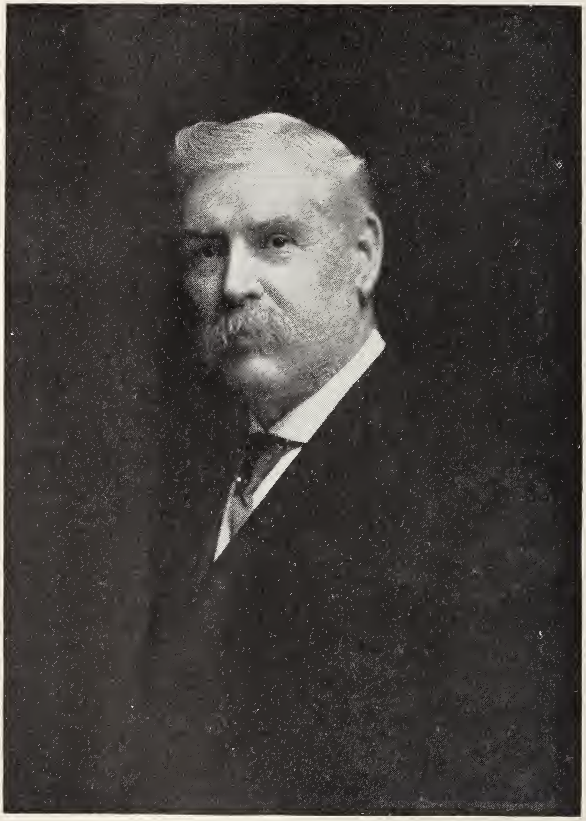
" The passing generations have called to our country many aliens who are now living here with us. The coming generation of engineers will employ many of these aliens, and you men must bring their ideals up to the high plane of your own. Your duties are greater than the duties of those who have built the great railroads and canals, and brought these aliens into our country. Many of these men have come from parts of Europe where they know nothing of responsibility to government such as we know. It is for you to uplift their ideals.

" I was very glad to hear Mr. Jones refer to military training, and of the manner in which the sentiment was received. There is no place where one can acquire executive ability better than in military training, the training whereby a handful of men, such as our Mounted Police, can maintain law and order in such a vast territory as our Northwest, or the preserving of order in India, where a few British troops are surrounded by hordes of semi-hostile people. Such things are possible only by discipline, the discipline which is maintained throughout the entire British army and navy. This is the best school to teach it, and it will be of service to you throughout your whole life."

Mr. R. A. Sara, '09, then proposed the toast, "Canadian Industries," and Mr. R. S. Gourlay, the President of the Toronto Board of Trade, was called upon to reply to this toast.

Mr. R. S. Gourlay.

"You have asked me to respond to the toast of 'Canadian Industries,' and at the outset I would compliment you on the term used. It is not as we hear it so frequently in tariff discussions, ' a few manufacturers,' but Canadian Industries, which cover an area from the Atlantic to the Pacific, which I cannot illustrate better than to give you a picture of my experiences last summer in Kelowna, B.C., where the first manufacturing plant was started last year by a man who had hitherto been simply a grower, and also a little village of 125 inhabitants on the Digby Neck, N.S., which is typical of the whole of Canada. I found there a contented happy settlement, its people engaged in agriculture and fisheries, and the product of the fishery being cured, smoked and packed for the market, even to the making of the cans, whilst, in addition, a buyer purchased another part of the fishing by-product for the export to the United States for manufacture into isinglass, because we have, as yet, no manufacture of this commodity in Canada.



Mr. R. S. Gourlay.

"This, I say, is a picture of the whole of Canada. During the past few years industries have and are being established everywhere so that we now employ in Canada some 445,000 people in these industries, and if we allow a modest estimate for those dependent on them we have easily a million people who are directly supported from these industries, at least one-eighth of our population, without numbering at all the professional, commercial and transportation classes, who also derive the larger part of their incomes from these industries, indirectly it is true, but none the less surely.

"Another thought I would present is that though our industries are making progress, the output last year being estimated at a billion dollars, yet we are as yet only on the highway to being an industrial nation, as our customs imports show us that we imported some $300,000,000 worth of manufactured articles last year, much of which is sold in competition with the same class of goods made in Canada, and the balance because, as yet, we have not entered upon their manufacture.

" For instance, Canada has deposits of silica, yet we make no plate-glass, no window glass and no glass blocks for cutting. Our glass manufactures cover only a fraction of our importation and are confined to bottles, fruit jars, chimneys, globes, and tumblers, with practically none of the finer glass products.

" Again, consider our immense deposits of clay everywhere, and yet beyond building material we only make brick and the common classes of tiles, flower pots, and earthenware, nothing of such table and artistic ware as we use every day, and without which our homes would look poverty stricken if they had to use only made-in-Canada clay products.

"Truly in these classes of industries many lines have not yet reached ' the infant stage,' and so is it in other directions, and there is, therefore, much room for you, young men, who are to go out as leaders and experts in industrial life, to apply your knowledge and see that we make even more rapid progress in the way to becoming a fully developed industrial nation.

" Still another thought—the Government statistics indicate that the relation in Canada between workmen and master is more ideal than elsewhere, in the matter of wages, for the Government statistics show that in Canada much higher wages are paid than in Great Britain and Germany, and wages fully as high are paid in Canada as in the United States, where by the use of larger plants and greater development in specialization the output for the same wage is from 20 to 25 per cent. greater per workman. Whilst a still further indication of this happy, ideal condition between the master and men is revealed in the Government labor reports as to strike conditions. Last year with 445,000 workers there were, small and great, only 68 labor disturbances, affecting 17,000 employees, and that from these if you count out 12,500 employed in mining, building trades and transportation companies, there were but 4,500 people interested in all industries from fishing to street laborers, who, even for a period of a day or two were in any labor trouble, just 1 per cent. of the working force, a record such as cannot be found in any other country under the sun.

"In a word, you are entering on your life labor at a time when Canada is fairly on the highway to being, if not checked, a fully developed industrial nation, with conditions that are at present more ideal than elsewhere, when between master and man there is that spirit of co-partnership that more than aught else will make this country a great industrial nation.

"It is for you, young men, to rightly apprehend and cultivate this spirit, that combined with your skill in specialization and expert trained guidance will so increase the output, augment the workman's wage and the employer's profit as to develop still further this ideal condition.

"I have but one more thought. I am old enough to have begun business at the time when I had to choose between remaining in Canada with limited prospects or to leave for a field of larger possibilities, and I stayed, when the large number of my boyhood friends were finding work to the south of us. The emigration from Canada was enormous, young men of to-day cannot comprehend how enormous, and I also have lived through a period when Canadian industries were so few and far between that Canadian products in my line had to be sold with a guarantee that if they did not please on trial, they would be replaced for the purchaser with American products. But we are past that point, and now the Canadian product is recognized in all parts of the world, as of a class that in point of merit averages a standard that is not excelled in any other country.

"Young men, this fruitage of past years is your heritage, prize it highly, don't part with it, or do aught to lose it. It is your birthright, don't for any temporary advantage become an Esau and sell it for 'a mess of pottage.'"

President Campbell then called upon Mr. L. R. Wilson, '09, to propose the toast "The Legislature." In doing so Mr. Wilson reviewed the interest the Legislative Assembly had taken in the engineering progress of the country, and in endeavoring to further technical education. He made mention of the splendid work the different departments of the Legislature, especially that of Public Works and in the Department of Agriculture.

The Hon. J. S. Duff, in response, expressed his appreciation on the subject of military training for the Canadian boy, and also voiced his intention of watching with interest the great progress of the University, especially of the Faculty of Applied Science.

"The University" was proposed by J. Galbraith, Jr., who likened its success to that of its football teams, and pronounced "team work" as being the mainstay of success in both. He voiced the appreciation of the student body with regard to the magnificent gift of buildings lately presented by the Massey estate.

President Falconer, upon rising to respond, was received with the usual enthusiasm, which bespeaks the place he holds in the hearts of the undergraduates of the Faculty of Applied Science.

President Falconer.

"It was an excellent idea of the Engineering Society to invite here to-night Dr. Robertson, also the members of the Toronto Board of Trade, because many of your will go out and engage in the industries represented by these gentlemen. You engineers must more and more tend to bridge the gap existing between educated men and the class that have often thought themselves to be the unprivileged class, because the privilege of education has been denied to them. You men will come in contact with workmen, and it is through you that some of the benefits of education will reach them. These benefits will enter into the finished product, and also into the life of the man while the product is being brought to its completion.

" Does the engineer work only for the completion of any building or any great work? Ask your graduates in New York whether they sit still and contemplate the building when it is finished. Is that their attitude? By no means. As soon as one piece of work is done they look for another. Enjoyment comes not mainly in the completion but in the process. Day by day you will be putting into the workman the desire to do his work with all his intelligence, and you will be adding to the contentment of his life and to your own happiness. This is the secret of industrial efficiency of the highest sort. To set a high ideal and to realize the ideal is what we aim at in the University and in the Faculty of Applied Science. You are trained to become engineers, but beyond this you must put into the engineering work the purpose of your life, and this cannot be fully reached apart from the development of those who with you carry your engineering designs into execution."

In replying to the toast " The Faculty," proposed by Mr. Chas. Webster, Dean Galbraith commanded the rapt attention of every hearer as he reminiscently reviewed the progress of the " School " since the days, thirty years ago, when Dr. Ellis and himself constituted the teaching staff, and the total enrolment consisted of seven students.

" It would delight the hearts of the founders of this institution and of those who taught here with me first, to see the class which numbered seven when we commenced, grown to nearly eight hundred.

" In the olden days the teaching was done by men from the Colleges. They were well up in their subjects but they had not been out in the world and lacked the contact with actual conditions. One of the great changes has been in the type of men on the faculty. We are cut off from the outside here, and one of the strongest tendencies as a university becomes more immense is to sever the bonds to a greater extent still. It is the duty of our graduates to bring back to us the fruits of their experience in the world with the learning gained here, and to keep us in touch with the outside."

The Dean referred briefly to his recent visit to Cobalt as a guest at the S. P. S. Temiskaming dinner, and praised the work done there by students.

"We are not afraid of lack of success for our graduates, and we are sure of their ability to carry on the work for which they were trained."

Before rising Dean Galbraith was greeted with a chorus from the undergraduates as follows:

"Long live our Dean!
Don't you hear them cheering?
Don't you hear them shouting as the Dean goes by?
Long live the Dean! That's the song we sing,
God bless our Dean! is the students' loving cry."

Mr. W. A. O'Flynn proposed "The Engineering Profession," and coupled with it the name of an old and most successful graduate, W. J. Francis, C.E., of Montreal. The address of Mr. Francis, as that of one student to others, appealed strongly to every student and young graduate present, and could not have been replaced by a more fitting or more appreciated response.

After some humorisms, referring more particularly to school affairs, he quoted Tredgold's historic definition of the Civil Engineer as one who directs the great sources of power in nature to the use and convenience of man. Measured by that standard, the man who employs the electric current to move the wheels of commerce is a civil engineer in the field of electricity; the man who sinks a shaft or drives a tunnel is a civil engineer in the art of mining. The name and the work it implies are most comprehensive and inclusive in their significance. Expressing his great satisfaction that the civil engineer is no longer considered a sort of glorified plumber by the public and that the profession is rapidly taking its place beside those other professions of law, medicine and theology, the speaker made the statement that the reason this condition was so much delayed lay largely with the engineers themselves.

He deplored the practice of many engineers in lobbying for work, and in countenancing the action of individuals and corporations in need of the services of an engineer, who are seeking the lowest bidder regardless of qualifications or reputation. As a parallel between engineers and their clients, he pictured a number of doctors bidding for a surgical operation and the patient in the throes of appendicitis waiting the results of the tenders in order to determine who would do the carving for the least number of dollars.

Proceeding, he spoke of the Canadian Society of Civil Engineers as probably the "greatest professional organization in Canada to-day," and as one which is doing excellent work in elevating the status of the engineering profession, and in endeavoring to create of standard of engineering ethics in Canada. That society, he said, had signally honored the University of Toronto. Dean Galbraith is a past president, and Professor Haultain and many of the other graduates are councillors. A good number of the graduates are members, and the others should all be connected with the Society. Mr. Francis urged the students to affiliate themselves with the Canadian Society of Civil Engineers and so assist in the establishment of a high standard of professional conduct.

Mr. W. J. Francis, C.E.

He referred reminiscently to his student days at Toronto twenty odd years ago, when the staff consisted of Dean Galbraith, Dr. Coleman, and Dr. Ellis of the present staff, and a few others who have since crossed the Great Divide. "We didn't call him the Dean then, we called him Professor—when he was there; you know what we called him when he wasn't there." Those were the days of "the little red schoolhouse" for the engineering student. In the years that have passed since then, great expansion, at that time not even dreamed of, has taken place, but "Five o'clock, gentlemen!" still resounds through the old building. In his closing remarks, he urged the students to master the fundamentals, and to be thorough in their work. He told them they had chosen for their life work that profession which had more to do with the world's wonderful advancement than any other, and advised them to adhere to that straight and undeviating line of conduct which should at all times characterize an engineer. By doing these things he felt that in future years they would reflect credit on their Alma Mater, which he regarded as one of the "greatest institutions in the Dominion."

The lengthy programme of speeches was relieved by musical selections, rendered in a most pleasing style by the Science Octette, the members of which this year are, Messrs. W. A. O'Flynn, W. A. Costain, P. S. McLean, G. B. Macaulay, J. H. Craig, W. C. Blackwood, R. B. Chandler, G. J. Mickler. The Octette is again under the leadership of Clayton E. Bush.

The success of the twenty-second annual dinner is due to the united efforts of the entire executive, and to the able assistance of Prof. Wright and others of the staff.

W. T. Main, '93, is division engineer, on the Wisconsin division of the C. & N. W. Ry.

W. G. McGeorge, '08, is conducting a general engineering practice in Chatham, Ont.

A. T. C. McMaster, '01, is engineer on design and construction of basic converter and reveberatory plants, The Canadian Copper Co., Copper Cliff, Ontario.

J. L. Morris, '81, and W. J. Moore, '06, are in partnership at Pembroke, Ont, under the name of Morris and Moore, surveyors and general engineers.

A. E. Pickering, '04, is with the Lake Superior Power Co., as superintendent.

R. S. Smart, '04, is in Ottawa, as manager Fetherstonhaugh & Co., Patent Solicitors.

P. H. Stock, '09, is resident engineer, for the Niagara, St. Catharines and Toronto Ry.

W. V. Taylor, '93, is Harbour Commissioner for the city of Quebec.

A. F. Wells, '04, is president of the firm of Wells and Gray, Ltd., engineers and contractors, Toronto.

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A FEW POINTS ON REINFORCED CONCRETE DESIGN.

C. S. L. HERTZBERG, '05

In designing reinforced concrete structures, one is continually meeting minor problems upon which very little satisfactory information can be obtained from the numerous treatises on the subject. In the following paper I shall endeavor to enumerate a few points in design which are sometimes apparently not given the attention they deserve.

Footings have probably given more trouble to the designer, the erecting contractor and the owner than anything else in connection with reinforced concrete. Unequal settlement in footings is responsible for numerous unsightly deformities and cracks and some collapses.

The common type of reinforced concrete column footings is, of course, easily dealt with, and differs from a plain concrete footing only in its being designated as a flat slab to resist bending, instead of being sloped off as a pedestal. In this type of footing the centre of pressure coincides with the centre of gravity of the footing area, and the required size is formed directly from the load to be carried and the resisting power per square foot of the soil. Trouble is sometimes caused by having a footing too large in comparison with the size of the other footings in the same building. This is particularly liable to happen in the design of wall column footings in the following manner:

If the footings are designed to carry the total dead and live load, figuring each flooring of the building fully loaded, then the interior footings will, under probably loading, not stress the soil as highly as will the wall column footings. The reason for this is, of course, that the load figured to come on the wall column footings is usually about 70 per cent. dead load (which is present under all conditions), and 30 per cent. live load (which is never all there), while that figured on the interior column footings is generally about 40 per cent. dead and 60 per cent. live. As the live load on the footings of a building of five storeys or more is never more than 50 per cent. of the total live load, it will readily be seen that the pressure per square foot is less on interior footings than on exterior ones.

As all soil is compressed under any loading, the interior footings will not settle as much as the exterior ones, and the result is sometimes the cracking of floor beams and slabs.

The difficulty is overcome, to a certain extent, by the custom of reducing the live load by about 50 per cent. in buildings of over a certain number of storeys. This, however, would appear to be insufficient, and it would seem that either a greater reduction should be figured in designing interior column footings, or else no reduction at all should be allowed in figuring exterior footings. It would also appear to be wise to even add a small

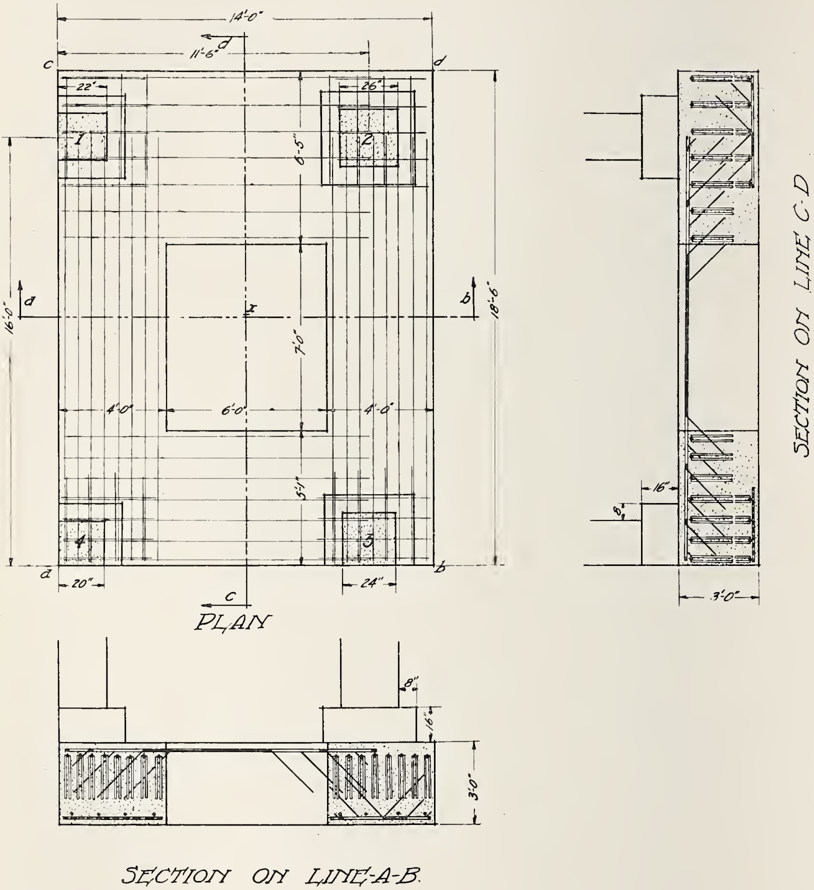


FIG. 1

percentage on corner column footings, as a much larger portion of the wall coming on these is dead weight.

It very often occurs that the footings under wall columns cannot be built to extend beyond the outside line of the column. In cases of this kind some sort of combination footing should be used. This is sometimes done by carrying the column in question on a cantilever beam, pinned down at the other end by one of the other columns. Care must be taken in this type to reduce the footing under the second column in proportion to the upward thrust from the end of cantilever beam.

A simpler method of treating the above is as follows:

Consider the wall column in question and the nearest interior column as acting together on a combined footing. Figure the loads coming on both columns and find the position of their resultant load. Add the two loads and divide by the soil value per square foot. This will give the required footing area. Design a footing of this area and varying in width from one end to the other in such a way that the centre of gravity of the area will coincide with the point of application of the resultant from the two column loads. The thickness of the footing and the reinforcing material must now be designed, treating the footing as an inverted beam, supported at the two columns and resisting the upward pressure of the soil, which will be of an intensity per square foot equal to the soil value minus the weight per square foot of the concrete in the footing.

The above method can be used for designing combination footings for any number of columns.

Figure I. shows a footing of this type designed to carry the four columns indicated, whose loads were: 1: 267,000 pounds; 2: 347,000 pounds; 3: 284,000 pounds, and 4: 197,000 pounds. The soil value assumed was 5,000 pounds per square foot. Column 1 was a corner column, 2 and 3 were wall columns, and 4 was an interior column. The footings could not extend beyond the lines A. B. and A. C. The footing was designed as follows:

Sum of column loads = 109,500 pounds.

Sum of moments about side a.b. = 10,272,166 foot pounds.

Therefore centre of pressure is $\frac{10272166}{109500} = 9'-4\frac{1}{2}''$ from a. b.

Taking moments about line a. c. we find centre of pressure is 7 ft. 0 in. a.c.

This locates the point x, the centre of pressure.

Area of footing required $= \frac{109500}{5000} = 219$ sq. ft.

The lengths, 18 ft. 6 in. and 10 ft. 0 in. of the sides a.c. and a .b. are now arbitrarily assumed.

Area of rectangle a. b. c. d. = 259 sq. ft.

Area of footing required = 219 sq. ft.

Area to be deducted = 40 sq. ft.
Deduct area, E.f.g.h. 7 x 6 = 42 sq. ft.

Let x = distance from a. c. to centre of gravity of area to be deducted.

Let Y = distance from a. b.

$$\text{Then } x = \frac{259 \times 7 - 217 \times 7}{42} = 7 \text{ ft. } 0 \text{ in.}$$

$$\text{And } y = \frac{259 \times 9.25 - 217 \times 9.38}{42} = 8 \text{ ft. } 7 \text{ in.}$$

which locates the position of the area E.f.g.h., which will give a footing whose centre of gravity coincides with the centre of pressure x.

The footing was then designed for bending by treating it as four beams between the four columns, figuring on 5,000 pounds per square foot upward pressure minus the weight of the concrete in the footing.

While the centre of pressure will, of course, shift under different conditions of column loading, still the variation cannot be sufficient to cause a serious settlement of any part of the footing.

In some cases it is very difficult to economically combine a wall column footing with any other footing. Where this is the case the footing is increased towards the inside of the building and along the wall. When this is done, the column must, of course, be tied in at the top and figured to resist the bending caused by the eccentric loading on the footing. This bending is generally increased by the bending moment from the eccentricity brought on the column from the floor loads.

A point in designing reinforced concrete which is often overlooked is the bending produced in wall columns carrying long span beams. This moment seldom gives trouble in the lower tiers of columns in a building of any considerable height as, in such cases, the columns are so heavily loaded that the eccentricity is not sufficient to produce actual tension in the outside of the column.

The common practice of designing wall columns 20 per cent. heavier than interior columns does not always overcome this tendency to crack from bending, as the extra strength is not applied in the proper place.

Consider the roof columns of a building of considerable width in which the roof beams span from side to side with no intermediate support. The usual custom is to carry the column reinforcement to within a few inches of the top of the roof slab and to bend the anchor bars of the beams down into the columns the usual depth to prevent cracking in the upper surfaces of the beams near the ends. In a building designed in this way the result is pretty sure to be cracks across the outer surfaces of the columns immediately under the level of the bottom of the beams, even though the roof be under no load other than the dead load of the structure itself. The reason for this is that the beam deflects under its own weight and the weight of slab carried. This deflection produces a tension in the upper surface of the beam at the end, which tension is also present at the outer surface of the column, where it is altogether liable to produce large cracks. These cracks can be seen in many buildings. They should be provided against by increasing the reinforcing steel in the outer side of the column. This reinforcement in these columns (if the same are not bent over as described) increases the liability to crack, owing to the fact that they must be embedded to a greater distance than deformed bars in order to develop their tensile strength. Cracks of this nature are, of course, more unsightly than they are dangerous, for beams supported in this manner are usually designed as non-continuous over the supports and should be of the required strength, whether pinned down to the columns or not. However, the bond with the column is an added strength to the beam and should be preserved.

The placing of brackets under a beam of the above description does not overcome the difficulty and is, in my mind, poor practice. The brackets tend to spread the columns by causing the beam to act as an arch whose thrust is not properly taken care of, and cracks will very likely occur on the outer surface of the columns under the brackets. This construction acts, to a great extent like roof truss without a tie rod.

Reverse bending should be given particular attention in the design of highway bridges where heavy moving loads have to be provided for. In short span culverts, where a flat slab is used, this reverse bending at the abutments, if not properly taken care of, may result in a failure which has all the appearance of a shear failure, and such it may be after a certain point, although it has probably started in tension cracks in the upper surface of the slab.

Consider a culvert, let us say, of 12 feet clear span, to be designed to carry a 15-ton road roller. The slab is designed as non-continuous, and enough steel is inserted in the bottom to give a resisting moment to properly take care of the total maximum bending moment liable to come on the culvert. In all probability the concrete itself will figure to take care of all the shear at 50 pounds per square inch, and therefore no extra provision is made against through shear.

At first glance this culvert would appear to be properly designed to insure against failure from any cause, for, as the slab is not figured continuous over supports, it does not seem necessary to put any steel in the top of the slab at the abutments. This conclusion would be safe if the slab were cast separate from the abutments, but if (as is nearly always the case) the abutments and slab are monolithic, the following is liable to occur:

A heavy, vibratory load comes to the centre of the span and produces considerable deflection and, as the slab is tied down to the abutment, tension is produced in the upper surface of the slab and on the outer surface of the abutments. The slab, being thinner than the abutment, cracks on top just inside the line of the abutment. Then, as the load approaches this point, the shear is increased and the cracked concrete is probably not capable of resisting this shear, and collapses. This failure might have been prevented in three ways, namely, by the use of top steel, by the use of steel shear members, or by having a complete horizontal joint between the slab and abutment.

The advantages of what is known as flat ceiling construction are many, the most desirable among them being the appearance produced and the economy in floor height. The chief disadvantage in the most common types is our lack of scientific data on the subject. In a well-known type, opinions differ nearly 100 per cent. as to the bending moment to be figured in slabs under the same loading. In the Engineering Record of 24th December, 1910, there is an account of some measurements made to obtain the strain existing in different portions of a flat slab floor under working loads. From these strains the existing stresses are figured. The results of these measurements appear to indicate that some designers are over sanguine about the carrying capacities of this type of floor.

A more conservative design of flat ceilings is effected by increasing the width of the beams and decreasing their depth until the under side of the beams is flush with the under side of the slab. The slab in these cases is usually made up of small reinforced concrete joists with tile fillers in between, and two or three inches of concrete over the top to aid in compressive resistance.

In this type of floor the stresses are known and the strength can be figured along the same lines as the ordinary slab and beam construction. The tile fillers are placed as much as possible below the natural axis of the slab so as not to decrease the dead load of the floor. This type of floor is not as economical in steel as the usual slab and beam construction, on account of the decreased arm of the resisting couple of the steel in tension and the concrete in compression.

To-day, reinforcement in a rectangular panel, designed according to the accepted theory of reductions in bending moments, effects economy in concrete only. If the bending moments each way be reduced in the usual manner of multiplying by $\frac{B^4}{A^4 + B^4}$ for the shorter span and by $\frac{A^4}{A^4 + B^4}$ for the longer, where A represents the shorter span and B the longer, the steel may be slightly reduced by placing less near the edges of the panel than near the centre. This reduction is, however, offset by the fact that, in using bar reinforcement, the amount of resistance of the upper layer of steel is decreased by the decrease in the resisting arm of the forces. The saving in concrete is, of course, effected by figuring it to take its full working compression in two directions at right angles to one another.

Before closing, I would like to enter a plea for the standardization of unit stresses and formulae in reinforced concrete design throughout Canada. Some things, of course, cannot be standardized, but such points as ratio of the moduli of elasticity of steel and concrete, the allowable working compressive strength of concrete, both in bending and in direct compression, the limits of Tee action, etc., might be definitely settled and adhered to by all designers. If it is safe in one city to design a continuous beam uniformly loaded to resist a bending moment of one-twelfth WL, then it is equally safe to do the same in the next city, despite the fact that the second city insists on it being designed for one-eighth WL. Other points might also be straightened out, such as whether a specification should insist on using 12 for the ratio of the modulus of elasticity of steel to that of concrete, when in another part it calls for working stress of 350 pounds per square inch for the concrete in a column and 10,000 pounds for compressive steel embedded in the same column.

INSPECTION OF CONCRETE.

E. A. JAMES, A.M., Can. Soc. C.E.

Although concrete was a material of construction in the days when the Roman Empire flourished, yet we speak of it as one of the modern materials of construction. For several centuries other materials were more convenient and more fashionable, and with the settlement of America the plentiful supply of timber and the ease with which it was made suitable for construction work, marked timber the cheap material of construction, and it was not until the '70's that cement and concrete again entered into construction work in any great quantities.

To-day, the annual consumption of cement in Canada is close unto five million barrels, which represents in completed structure many times five million dollars' worth.

Where the uses are so varied, as are those to which concrete is placed, it is but natural to expect to hear of failure, and where the amount of money expended annually is so large, it is reasonable to suppose that every effort should be made to ensure good work.

In concrete work, as in other classes of construction, good design and good materials are necessary, and, granting that we have good design and good materials , a class of well-skilled workmen should produce a finished material of a high order.

Concrete, however, has suffered more than any other building material because of inferior workmen, and this has been brought about largely by those interested in the early days in the sale of cement, who claimed as one of the chief reasons why it should be largely used, was the cheapness of placing, because it did not require skilled laborers.

Fortunately, we do not hear so much of the claim as formerly, for it is well recognized that workmen can, with the same ingredients, produce various grades of concrete.

Although among the first of the modern concrete structures many were well and substantially made, yet there were a number of serious failures, and because the engineers themselves were not any too familiar with concrete construction, and because of this recurring failure and the fact that most of the workers in concrete were men imperfectly skilled, a system of careful inspection was inaugurated.

While the necessity of inspection depends to a certain extent upon the nature of the material and the production, it is always a question of just when and where and to what extent it pays to inspect. In concrete work inspection must be made of the component parts, the sand, the gravel, the cement and the water must be examined, as well as the concrete, while it is being mixed and poured.

The scope and possibilities of a system of inspection enlarges greatly with specialization.

Inspection should be planned to accomplish at least expense, the best results, which may be numerated something as follows:

1. To prevent loss or defects by accidents or delays.
2. To prevent loss of time and material on work already beyond repair.
3. To prevent the necessity of replacing defective work.
4. To prevent decrease in quality because of the demand for increase in quantity.
5. To point out imperfections in alignment, methods and material.
6. To record proper allowances for unavoidable extras.
7. To draw the attention of the superintendent to workmen who must be better instructed or trained.
8. To stimulate good-will through fairness, in fixing responsibilities.

Inspection organized to cover any one or all of these purposes will be similar in personality, varying only with the degree of perfection required.

Before it can be determined just when and where it pays to inspect, the following conditions must be satisfied:

1. Responsibility must be fixed with certainty.
2. The inspection must not cause unnecessary friction.

3. The inspector must have to do with equality only, not design.

4. The responsibility for defective work must be placed upon the workman as well as upon the inspector.

Responsibility must be fixed with certainity.

As inspection has for its purpose the pointing out of the defects, it is necessary for the inspector to be able to locate the cause of the defect. One of the most foolish things that can be done is attaching blame to the wrong person, and unless it is possible to discover immediately just when and where the cause of the defect lies, the fixing of responsibility is very difficult. It is, therefore, necessary to have the material on the ground in sufficient time for thorough inspection before it is mixed, for even after the inspector has detected the defect, the responsibility is not necessarily fixed. The error may be due to wrong specification, poor material, defective measurement, defective mixing, or even unsuitable weather conditions. It is, therefore, necessary that instructions and specifications must be in writing.

Inspection must not cause uncessary friction.

No system of inspection which would simply complain of defects, without attempting to trace the cause, or to assist in the improving of conditions, will be of any assistance. It certainly would not tend to happy relations between contractor and engineer. So it becomes necessary, if full benefits are to be derived from rigid inspection, not only to point out the defects, but the inspector should be in a position to trace the cause and to suggest a remedy. Defective work must be detected as soon as possible, so that the conditions under which the work was done may be fresh in the workman's mind, and the responsibility with certainty attached to him when the defect it through careless workmanship.

The inspector must have to do with quality only, not design.

To point out defects will not necessarily stop the repetition and, although it may be the duty of the inspector to trace the cause, fix the responsibility and suggest the remedy, the inspector must not have to do with applying the remedy or of interfering with the workmen

When the inspector has reported defects in material or workmanship to the engineer and contractor, or their representatives, he must content himself with awaiting the corrections through the proper officials, although it should be within his power to stop or reject the work until there is an opportunity for investigation, and to take upon himself these responsibilities, he must have knowledge equal to that of the superintendent of the work.

Responsibility for defective work must be placed upon the workman as well as upon the inspector.

While we have stated that the inspector should not interfere with the workman, yet the knowledge that he is present will have a disciplinarian effect and will prevent the sacrifice of quality for quantity. Inspecting alone will not reduce bad workmanship to a minimum, but the workman must be supplied with proper tools, proper instructions, and must be trained in his work and held responsible for the quality of his work. He must be trained to inspect his own work. We have known cases where the men were paid a bonus for saving cement, and where this is the case it almost requires as many inspectors as men to secure compliance with specifications. Where it is known that the contractor is encouraging his men to skimp the work, the inspector should lay his information before the engineer, and at once vigorous measures should be taken to remove such contractor from the work, for he will not do good work, no matter what the inspection is.

Plan of Inspection.

There are many plans of inspection, any of which may get good results, and all of which may fail in securing good results. Inspection depends more upon the inspector than upon the method.

You may have inspection by central bureaus which retain men who are experts in their line of work, who report first to their bureaus, or to the engineer in charge of the work, as may be arranged.

You may have inspection by your own local staff or foreman, or you may require such guarantee that inspection at the end of one or two-year periods will be all that is necessary. The plan of inspection to be adopted will necessarily depend on the character of work being carried out.

The Duties of the Inspector.

It should be the duty of the inspector to see that all forms are erected on the lines laid down by the engineer, that these forms are stiff and well braced, and that all material and workmanship are in accordance with specifications. He should look after the removal of forms and see that the concrete is not injured in the removal.

Aside from concrete walks, form work is the most difficult to get properly placed, and it is much easier to develop a good inspector out of a good carpenter than out of a good concrete worker.

If the work is to be done at night under artificial light, it will be necessary to increase the staff of inspectors, for concrete that can be detected in the day time, by color, will not show a lack of proper mixing of materials under artificial light. In fact, where high class work is required, or in finishing surfaces, as a rule, it is better not done at night at all.

The cost of inspection is variable, being in some cases as low as one per cent. of the total cost and as high as two and a half per cent. I think it is a usual thing two per cent. should be allowed for inspection, and good inspection is cheap at that price.

ELECTROLYTIC RECTIFIER.

R. H. HOPKINS, B.A., Sc.

Department of Electrical Engineering, University of Toronto.

The general use of alternating current for the transmission of energy for light and power, and the limitations of this form of energy for some purposes, makes necessary some apparatus for the transformation of alternating current into direct current.

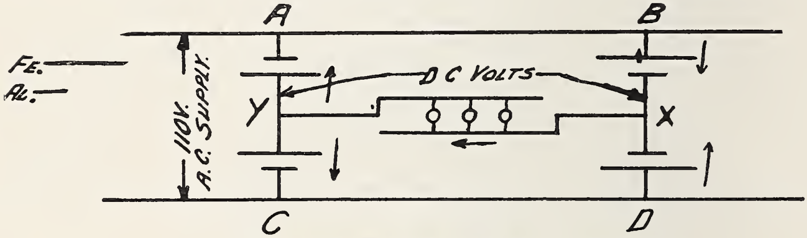
There are a number of methods available; the use of the motor generator set, the rotary converter, and the mercury arc rectifier, being some of them. Where the amount of power to be used is considerable, a motor generator set or a rotary converter will be used. When the amount of power to be used is small, and especially where it is used in charging storage batteries, these machines are not as satisfactory. Here, then, is the field for the mercury arc rectifier and the electrolytic rectifier. The smaller the amount of power necessary, and the more the first cost figures, the greater are the odds in favor of the use of the electrolytic rectifier.

The electrolytic rectifier is a chemical cell for the rectifying of alternating current. Its rectifying action is due to a high resistance to flow of current in one direction and not in the other that certain metals have when placed in some electrolytes.

If two plates of aluminium which have been charged (I will mention this later) are placed in an electrolyte such as a solution of ammonium phosphate, sodium phosphate, borax, etc., and connected to a direct current supply, no current will flow; if, however, we connect a plate of iron and one of aluminium to the same supply, the iron being connected to the positive line, the cell will act as a direct short circuit. It is hardly right to look upon the action of the aluminium as regards flow of current when it is an anode as being due to resistance. It is rather a counter electromotive force, which varies with the impressed voltage up to as much as 600 volts per cell. It also varies with the electrolyte. This counter electromotive force is due to a film of aluminium hydroxide that is formed on the aluminium. This film is very thin, being comparable in thickness to the length of a wave of light, and it seems to be formed of two parts, an insoluable shell holding a gaseous body.

If 110 volts be applied to a circuit consisting of two plates of aluminium in a solution of ammonium phosphate, an enormous current flows that rapidly dies to zero, and the plates are said to be charged. On examining the plates it will be noticed that they have a frosty appearance; this is due to the film that has been formed on them. The statement that the current drops to zero is not quite true, for if the voltage is direct you will have a minute leakage current, and if alternating, a leakage current, and superimposed upon it a condenser current of greater magnitude, but still of small value. Steinmetz says this current is about .01 ampere per square inch of plate surface, but does not say for what voltage or frequency. With plates of 10 square inches surfaces in an electrolyte of ammonium phosphate, a current of .35 amperes was obtained at 60 cycles, 110 volts, and with the General Electric Company's lighting arrester solution, a current of .15 amperes for plates of 20 square inches on 110 volts, 60 cycles, was obtained.

The connections commonly used for an electrolytic rectifier are illustrated in Fig. 1. On account of the impedance of the choke coil, practically no current flows through it, but intermittent direct current flows from the centre of it without a serious drop on account of the choke coil acting as a one to one series transformer. Let B be positive. Current cannot enter the solution by an alumium electrode so it flows to centre tap of the choke coil through the direct current circuit, to the iron plate, to the aluminium plate on the other side of the line. Now, this current flowing in the half of the transformer creates a magnetic flux, and unless this flux is balanced the current cannot flow freely. This flux is balanced by the flux created by a secondary or induced current to the other half of the choke coil, which is equal and opposite to the first current. It flows from centre point of coil through the direct current circuit to the iron plate, to the aluminium plate, and completes its circuit in the coil. Hence you will have twice the current at half voltage in the direct current circuit. These relations are theoretical and are not obtained in practice.



CONNECTIONS FOR 4 CELL RECTIFIER

FIG. 1

The connections for the use of an aluminium rectifier without a choke coil are illustrated in Fig. 2. There are four cells, each consisting of an iron plate and an aluminium plate in the electrolyte. Two cells are connected in series opposition with the aluminium plates connected to the supply, and two in series opposition with the iron plates also connected to the supply. Consider the line AB positive. Current flows from B to X to Y to C, and if the line CD be positive, current flows from D to X to Y to A. In other words, there is direct current flowing from X to Y independent of which line is positive.

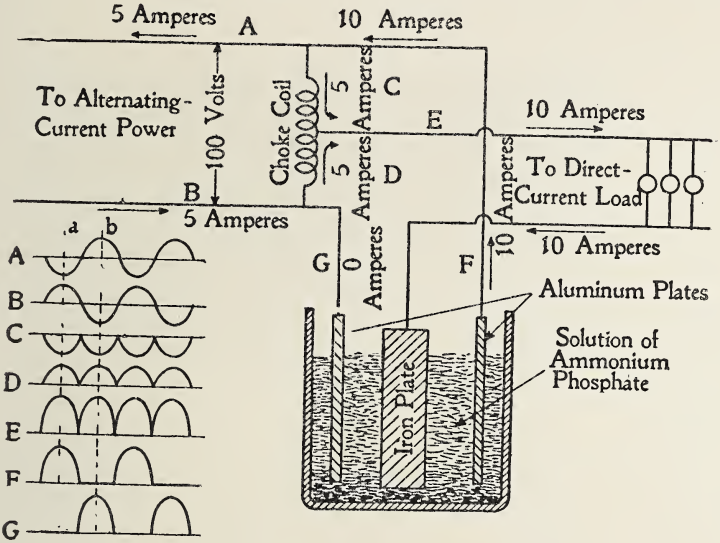


Fig. 2

The results that can be obtained from a small rectifier with connections made as illustrated in Fig. 1 are shown by a set of curves, Fig. 3. This rectifier had two aluminium plates two inches by seven inches, and an iron plate six inches by seven inches. The electrolyte was a saturated solution of pure ammonium phosphate. Figs. 4 and 5 are taken from oscilligrams of the voltage and current in different parts of the circuit. The alternating current supply was from an old, smooth core, ring-wound alternator, which explains the smooth curves. With a modern slotted armature alternator as a supply, the general shape of the curves is similar, but they are somewhat distorted by the harmonics caused by the teeth of the alternator. These harmonics are considerably amplified by the condenser action of the rectifier. Curve 1, Fig. 4, is of the supply voltage; Curve 2, the supply current, and Curve 3 shows the direct current voltage. Curve 4, Fig. 5, shows the direct current obtained, and Curves 5 and 6 show the components of 4, i.e., the currents in lines G and F. (Fig. 1). The theoretical values of the currents in the different parts of the circuit are illustrated in Fig. 1, the dotted line “a” indicating the values of the currents in the different parts of the circuit (which are lettered to correspond) at the instant current at B is flowing to the choke coil. The dotted line “s” indicates the values of the currents at the instant current at B is flowing away from the coil.

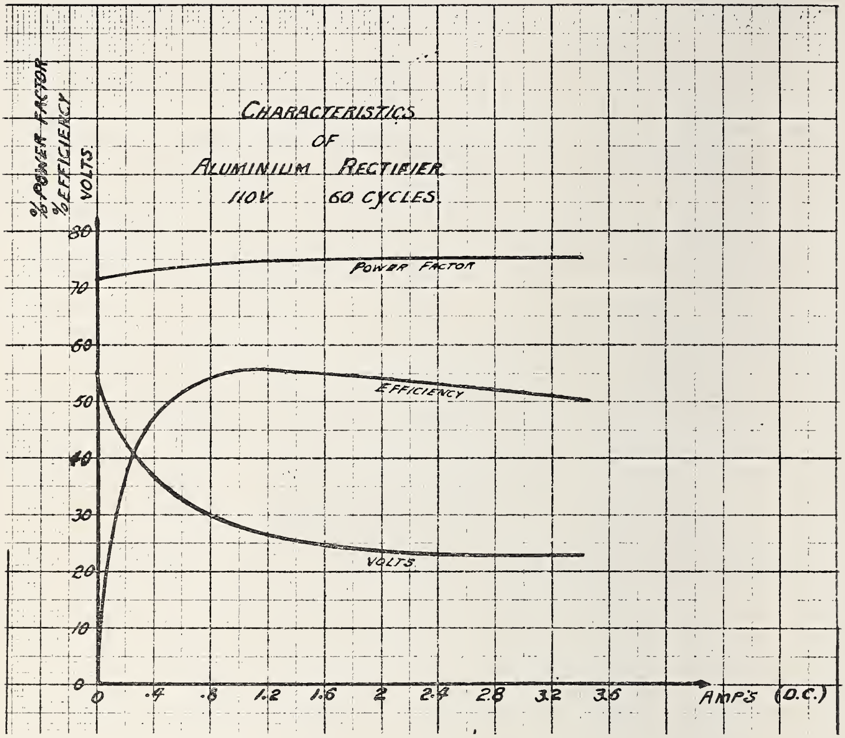


FIG. 3

These rectifiers are used commercially for charging batteries for electric automobiles, batteries for use with pipe organs,

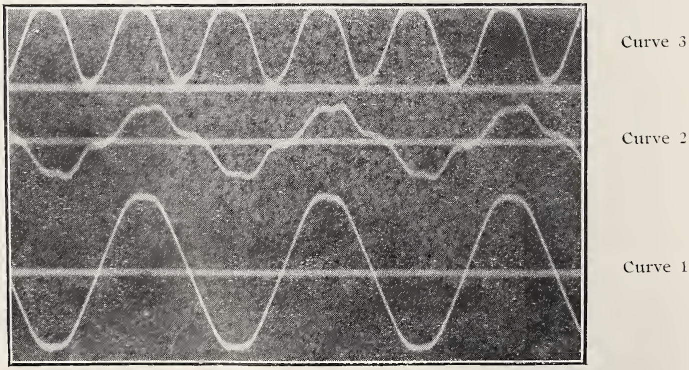


FIG. 4

and batteries for ignition outfits. Their main advantage is low first cost. The disadvantages are poor efficiency and large size. The efficiency is about 60 per cent. as a maximum, 50 per cent. being a good commercial efficiency. As to size, a rectifier for continuous operation, delivering three amperes, requires aluminium plates of twenty square inches each, and an iron plate of from seventy-five to one hundred square inches, besides which the cell must have a radiating surface of from three to four square feet. This radiating surface, unless some device for cooling is used, is essential, as the efficiency drops rapidly with a rise in temperature. The power factor is never above 90 per cent., but is not necessarily low, if the rectifier is fully loaded. The maximum voltage that can be used per cell is about one hundred and seventy-five volts. Above this voltage the breakdown voltage of the film is reached. The breakdown voltage may be increased by a change of the electrolyte, but this lowers the efficiency of the cell.

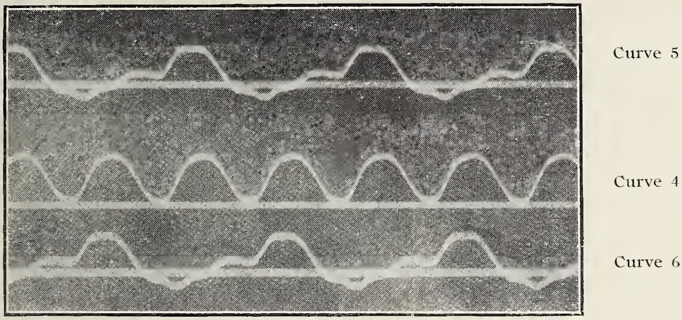


Fig. 5

As a cheap and good means of charging a few storage battery cells from an alternating current supply, the aluminium rectifier seems to give good satisfaction.

SEWAGE EFFLUENTS AND PUTRESCIBILITY.

T. A. DALLYN, B.A. Sc.

Engineer in charge Ontario Board of Health Experimental Station.

The subject under discussion, "Sewage Effluents and Putrescibility," is one to which our attention is being constantly attracted as Canada — more especially our Province — becomes more and more thickly populated.

As our friend and professor—Dr. Ellis—has told us, there was a time when one might conveniently dispose of all refuse by throwing it out of the window or around the back entrance. Indeed, it is only some fifty years since such was the custom in many places in England. In many of the fishing villages the accumulation of trade refuse, such as offal, was such as to make our present-day aesthetic standards stand back in fearsome horror. As was natural in conditions such as these, due to carelessness and lack of all sanitary precautions, disease and epidemics abounded. It was also natural for the sanitarians of that day, when the theory of the spontaneous generation of the organisms of putrefaction held sway, to believe that these rotting masses also produced the cause of the epidemics, the bacterial organ of disease being as yet only dimly suspected by some few workers in surgery.

We find many references, at this date, to the atmospheric conditions during these epidemics, and lengthy assertions upon the effect of the night vapours. Science and observation have since taught us that while these conditions, when prevailing for a considerable period, may lower one's resistance to bacterial invasion, yet they themselves are not the primary cause of the disease. Looking back, one may see many ways in which such conditions may affect the life of a community: (1) Drought lessening the dilutions of stream contamination; (2) Seasonal migrations to the upper reaches of streams which, lower down, act as water supplies; (3) Stagnation of streams, with the subsequent production of algae growths forcing whole communities to seek for other sources of supply where these secondary sources may receive graver contamination than the neglected one. Extent of turbidity and taste are not good nor safe guides to a hygienic water supply.

Pasteur, in his work on yeasts and ferments (1862), discovered a method by which he could sterilize all manner of putrefactive material by heat. Then using vessels that could be sealed while the contained fluid was still sterile, he demonstrated the keeping qualities of the putrescible material. This demonstration was the gravestone of the "theory of spontaneous generation," and the foundation of the latter work in Bacteriology. Like Pasteur, if we are to accomplish much along sanitary lines, we must have results to back up our theories. For example, if Hypo-chlorite is an efficient sterilizer, we must see a reduction in water-borne typhoid infection; in other words, we must look to our death rate reduction; with that proof in hand, we need little else. Now, as a matter of fact, Hypo-chlorite is a good disinfectant. Yet, until it was used in fairly large quantities, .6 parts per million, no appreciable effect was shown on Toronto's typhoid rate. Now, laboratory experiments would indicate that the use of 0.6 parts of available chlorine was unnecessary, and that 0.35 parts would be just as effective; but the practical demonstration showed very different results. Whether this was due to lack of data or insufficient measurements of water consumption, the author is not aware, but the facts are as stated. Hence in carrying on disinfection experiments, one must not place too great confidence upon the laboratory side, except as indicators. The place to look for the effect of your operations is on your sheets showing presence of typhoid, cholera, and other water-carried infections. You have had good reason to know that 0.6 parts available chlorine impart a very objectionable taste to the water. It is this objectionable feature, in connection with disinfection of water supply, that brings us back to our original subject.

If we can not readily sterilize without objectionable tastes a highly polluted drinking water, then we must get after the causes of this pollution and **disinfect** it in such manner that subsequent dilutions will remove all traces of the objectionable tasting disinfectant used.

Slow sand filters have done, and are doing, splendid work, but they are rather expensive to operate when high degrees of bacterial purification are required. Especially is this true where a lake water, such as that of Lake Ontario, is used, which carries a very fine sand in suspension during storms. The water when in this condition may plug a filter up in three or four hours. Then it becomes a race to keep enough filters clean to supply filtered water to the community. If the water was known to be fairly safe (i.e., all large polluting streams disinfected), filters of different size sand could be adopted which would lessen the frequency of cleaning, and allow the use of various mechanical devices to assist in removing the clogging surface—devices which, under ordinary requirements of filters, are prohibited because they either remove too much sand or else remove too much of the fine sand used in the filter bed.

Of course, we cannot provide for all the various agencies by which pollution occurs, but we can at least get after those which are so apparent as sewage effluents. Gentlemen, you and I are the men that must see to it. If we who possess the knowledge of the evil and the cure, do not agitate and insist on its use, then who will ? We surely cannot leave it to some happy shots of the reporters of our daily papers—for with conditions varying as they do in different places, the remedy must vary also. There is no cure-all, as some of our political newspapers would have us believe. There must be careful investigation, the judicious use of research laboratories and scientific epidemiological field work, not only in one community, but in all. Our municipal Boards of Health are trying to do what they can with inefficient and under-equipped laboratories, but without the backing of the men who ought to know—the doctors, chemists and engineers—how can they go to the electors and councils to ask for the necessary funds ? Gentlemen, you may not care to put your life into sanitary work, but you can, and ought to, at least keep in touch with it and give it your scientific approval when circumstances permit, so that the public will at least know upon whose shoulders the responsibility lies.

In examining the results of the English analysis of sewage and sewage effluents, one is astonished to see the confidence with which systems are advanced upon the results of weekly and monthly analyses. It is only recently in our Canadian Engineer we had published a lengthy recommendation of the De-Clor process. Their experimental plant was in operation for twenty-one weeks, and in that time only twenty-one samples were taken. Does that not strike you as strange ?

The article lays special emphasis on the removal of B. Coli, so that it occurs only in 100 c.c. sample in the effluent, whereas in the prefiltered water it was present in 1-10 c.c. samples (i.e., a removal of 999 in 1,000) the bacterial count only showed a removal of general bacteria 885 in 1,000. Such results as these call for inquiry as to whether the removal of B. Coli is greater than for general water bacteria. The experiments at Mass. Institute of Technology indicate that it is about the same, and, if anything, a trifle lower, I want you to notice this point because it was further illustrated last fall by some rather curious results which came to my notice. The City Hall were making Bacterial analyses every second day, I believe, on tap water to detect B. Coli —sewage contamination. The Experimental Station was making analyses three times each day for purposes in connection with some experimental filters. Now, while the average of the every two-day set of analyses was not unlike that of the city for those days, the average of the three analyses a day was altogether different and showed heavy contamination. I am using this only by way of illustration of the point in question, namely, the value of frequency of analysis. It certainly makes a difference in bacterial work, and unless we, as scientifically trained men, know these things and, by knowing them, modify public opinion, a great amount of money is to be wasted in costly and inefficient apparatus. Remember, I am not saying the De-Chor process is inefficient—in fact, I like the idea. I am only saying that the published test was not extensive enough and somewhat misleading.

In sewage disposal there is, as a rule, two outstanding problems. (1) Disposal of trade refuse; (2) Disposal of domestic and factory sewage.

Now, there is no good reason why that trade refuse item should not be fought out with the manufacturers. Trade refuse is industrial waste. Take, for example, an instance in our own city here—that of the Harris Abattoir plant. At one time there was such a nuisance from their operations that the City Fathers, I believe, gave them notice to either remove the nuisance or shut down. They removed the nuisance and made a profit out of the waste. Now we have nothing entering our sewers from this plant save fluids from which even the grease that comes

from washing the floors has been extracted. What they have done under splendid management can be done by any other similar plant under equally efficient management.

With many other industrial wastes the problem is as yet unsolved, leaving splendid opportunities for research work under the direction of our faculty and among our graduates. Once the problem of trade wastes in a given centre has been partly solved it becomes a simpler matter to handle and purify the Domestic Sewage.

At present we have many processes for nitrifying sewage. From sewage farms and intermittent filter plants under proper management come splendid statistics, the sludge is digested, the effluent is clear and stable, only requiring disinfection as a final touch.

The question to which I would like to draw your attention particularly is still in the embryonic form as yet, but I bring it rather as a student to students, since it seems to me to be full of possibilities, especially for our Great Lake cities. I think we are generally agreed that in this enlightened age disinfection is a necessary feature of all sewage disposal problems. (1) Because it is not so very expensive; (2) The benefits to be derived are very great indeed in proportion to the expense.

Assuming disinfection necessary, can we not do away with this laborious nitrification, where large bodies of water are available for dilution ? If no process of purification and no disinfection is used, then we get conditions such as we have in our shameful Toronto Bay. This is not sanitary, nor is it a credit to any community in this twentieth century. Suppose we remove the suspended solids present in sewage by some process of sedimentation or chemical precipitation and then disinfect the effluent, will the effluent be stable in dilution ? That is the question. In the present paper I only wish to call to your attention some of the outstanding facts.

(1) We are seeking disinfection, not absolute sterilization.

(2) For stability, such that further putrification, if any, will take place only in aerobic conditions.

Disinfection is limited to the removal of pathogenic organisms. Of course, in process of doing this, we remove some 99.9 per cent. of the saprophitic bacteria, normally found in purtresible solutions, at the same time. Dunbar (1908) claims—and is no doubt right to within certain limits—" that by far the larger percentage of pathogenic micro-organisms are enclosed in gelatinous masses and attached to suspended matter." It, of course, is dependent upon the grade and rate of flow in your sewers whether these conditions exist at the disposal works.—" Hence any process which removes suspended matter removes also a large percentage of the pathogenic bacteria at the same time." " In some experiments on the removal of suspended matter in Hamburg River water, a removal of 30 per cent. of suspended matter gave a corresponding removal of bacteria, and this would be much more so in case of pathogenic bacteria in sewage." Some experiments of our own with Garrison Creek sewage have failed to show such good results. This sewer is laid on a considerable grade and has a velocity of between ten and fifteen feet per second, so that sufficient disturbance is created to largely remove bacteria from any such attachments. However, our experiments have hardly been extensive enough to speak dogmatically as yet. There is no doubt that in chemical precipitation, where the coagulants are of a colloidal nature, some good results should be obtained in removing a considerable percentage of pathogenic bacteria. Generally speaking, pathogenic bacteria may be expected to be more sensitive to disinfection than the saprophitic forms.

One may raise the question of operation of disinfection upon bacteria in spore formation. Fortunately, very few pathogenic bacteria are spore formers, and sewage is not a media in which spore formation is likely to occur if it has not already taken place. There is one, however, that may be mentioned. That is Enteriditas Sporogenes, a bacterium which some investigators claim gives rise to Diarrhoea, especially when present in milk given to young infants. This form is almost always present in sewage, and gives a fermentation reaction similar to B. Coli. The odors, however, are entirely different. This form has been recovered from sterilized sewage—by sterilization I mean disinfection a removal of 99.99 per cent. of bacteria, say a count of 1,000,000 being reduced to 200 and 186—which is a practical possibility) so that we have reason to believe it is more resistant than normal to chlorine. It is an anaerobic bacterium, and this is no doubt why it has been overlooked. If we were to take a known positive sample and inoculate eight fermentation tubes, we might only get four or five positives to show up, due possibly to the fact that anaerobic conditions varied in the several fermentation tubes. However, this is a little aside from the general question, where there is every reason to believe that forms such as B. Typhoid are entirely killed out, and they are the ones to which most attention has been directed.

In some experiments of our own, 1.2 parts per million A. Chlorine served to kill out one million bacteria (suspended in water) so that the water became sterile in 55 minutes. Of course, organic matter has an effect on chlorine usually from eight to ten parts per million are required to practically sterilize Garrison Creek sewage in one hour. These results are borne out also by the work of Earle B. Phelp at Boston some few years ago (1906). I think we may justly assume that the pathogenic bacteria are almost entirely removed, especially where sedimentation or fine screening have been used previous to disinfection. It is worth nothing that H_2S reacts readily with chlorine. H_2S is not as a rule present in raw sewage except as a trade waste from tanneries. But it is very much present in septic effluents—due to the decompositions of the proteids present, no doubt. Hence it is more economical to add chlorine to raw sewage than to septic tank. There are other reasons also why disinfection is preferable before septic treatment, such as the growth of anaerobic bacteria, etc. Septic treatment is, of course, unnecessary where we are using sedimentation tanks, and has, I think, been generally abandoned in favor of them, where large plants have been installed. Before leaving disinfection, let us remember one thing more, that is, that the chlorine deodorizes the sewage, so that if it be discharged two hours after disinfection we have (1) no odor, or, at least, very little, (2) the bacterial count per cc. varying from 100 to 500.

Water		Sewage 1-10 dilution
Chlorine	3 to 10	6.5 to 11.5
Nitrates	.43 to 4.95	Raw Sewage .04 and less Nitrified " 0.3 to 3.0
Nitrites	.0135 and less	R. Sewage .01 and less N. Sewage .3
Free Ammonia	.053 to .009	R. Sewage 3.9 to 1.0 N. Sewage .19 to .01
Album Ammonia	.066 to .007	R. Sewage .65 to .01 N. Sewage .01 and less

Note.—Values in Table a little high for sewage and a little low for river water.

If you will notice the accompanying table, some must observe that sewage in dilutions of 1-10 shows very little worse than a normal river water. It has, in fact, been offered to some English investigators as pure water. I do not recommend it myself without thorough disinfection, which they overlooked without serious consequences.

Having noticed the constituents of a dilute disinfected sewage, we may turn to its possible stability.

(1) We know that even this dilute sewage will serve to support high bacterial growths, but experiments have only been made at laboratory temperatures, that is, 18° C. and 37° C. Now, the normal for Lake Ontario is about 7.5° C. to 9° C. in summer, except, for surface waters, which may run to 16° C. With them, however, we have storms, and consequently higher dilutions. Then again these subsequent growths must take place in an aerobic media. In this connection, I would like to call your attention to several theories with regard to putrifaction. (1) A known fact is that obnoxious putrifaction takes place only in media where the supply of oxygen is exhausted, when we have such productions as H_2S and NH_3 formed, which otherwise becomes SO_4 radicals and nitrates. (2) These operations only take place due to very high bacterial counts. Alfred Fischer

(1900) states in his work, "The Structure and Functions of Bacteria," the following (see pages 99 and 100):

"Putrefaction is a purely biochemical process, and can only take place when the fundamental conditions for all vital action are fulfilled. If the temperature sinks below a certain point, organic substances cannot putrify, as was well shown by the frozen Siberian mammoths. When discovered, their flesh was so little changed that it was eaten by the hunters' dogs; yet it must have lain in nature's refrigerators for countless centuries. In all methods of preservation the fundamental principle is the same, namely, to create such conditions that bacteria cannot live; for putrefaction—the splitting-up of the nitrogenous constituents of organic matter—is the work of bacteria, and of bacteria alone.

"The list of putrefactive products is far from being complete, for even the qualitative investigation of the processes is still unfinished; quantitative analyses are at present impossible. We do not know, for instance, what determines the predominance of one or the other intermediate product. The effects of the presence of oxygen are somewhat better understood. If air have free access, putrefaction may go on without any odor at all, the evil-smelling gases (NH_3 and H_2S for example) being oxidized at once to form nitrates and sulphates. Aerobic bacteria, too, bring about this mineralization of organic matter, such as the nitre and sulphur bacteria. Moreover, when air is circulating freely there is no accumulation of intermediate products such as skatol or indol. This kind of decomposition proceeding without offensive smell, may be termed decay, as distinguished from putrefaction."

Now, do you see where we have arrived at in our theorizing? If we kill out those forms causing anaerobic putrefaction by disinfection and change of media so that only aerobic decay can take place, have we not arrived at a condition similar to the ordinary respiration of plants and animals, where energy is obtained from the combustion of a few molecules instead of that present in septic tanks, where the energy is derived from the incomplete combustion of many molecules?

Gentlemen, it seems to me we have a theory here that is worthy of investigation, and I hope at some future date to give you some of the experiments that will be adopted in trying it out, and our results therefrom.

AERIAL NAVIGATION.

CHARLES H. MITCHELL, C.E.

When asked by the President of the Engineering Society of Toronto University to prepare a paper for the Society on the progress of aerial navigation the writer was inclined to seek an excuse in press of other work. It occurred to him, however, that it was due the Society about this time to present a review of the development and progress of aerial navigation, as arising out of his paper on "Aerial Mechanical Flight," read before the same Society in January, 1895, and printed in Vol. 8 of the Society's proceedings. This paper was a resume of the science and art of aerial mechanical flight—if art it was—up to that time, and was compiled from all the sources of information then obtainable, which were scarce, indeed.

The principles enunciated in this early paper are now of especial interest in the light of the intervening history of aerial navigation and of the recent extraordinary successful operations of "heavier than air machines." The chances of the commercial development of mechanical aeroplane flying machines based upon the "everyday principles underlying the kite, the boomerang or the skater on thin ice" were then carefully studied and it was stated that "the perfection of aerial flight will come gradually, as did other perfected inventions which have revolutionized the whole world. We cannot look for any one man to thoroughly solve the problem, but it will be evolved from many sources, and these will at last contribute to the one long desired end." To still further quote this early academic brochure of sixteen years ago, the following significant enumeration of the requisites for a flying machine was made:—

"1. Its various parts and members must be of the lightest construction compatible with strength and stiffness, and the factor of safety must be large.

2. Its general configuration must be economical for space and convenience and present the least possible resistance to the air.

3. It must be capable of rising gently but swiftly and supporting itself in the air in storm or calm for a length of sion."

4. It must have stability and be incapable of upsetting.

5. Should be easily steered in any direction.

6. Provided with a means of rapid and powerful propulsion.

And the sentence is added: "This enumeration may appear highly idealistic, but the practical possibility is much clearer than is generally supposed."

That was sixteen years ago. It is needless to now draw attention to the present-day parallels of these requisites, or to ask to what extent they are fulfilled in to-day's aeroplane practice. But the art is only in its infancy, and who knows what another sixteen years will bring about? This is perhaps even harder to conceive when the progress of building and flying aeroplanes during the past three years is considered in the course of the general evolution.

The purpose of this paper is to briefly outline the development of aerial navigation, especially in mechanical flight, during the past few years, and to present some slight description of present-day uses and possibilities—particularly from a practical viewpoint.

Although primarily dealing with flying machines heavier than air, it is interesting to note historically the singular parallel evolution of the dirigible balloon which has almost kept pace with that of the aeroplane.

It is convenient to distinguish between the various classes of air craft according to their nature and functions. The most recent classification is about as follows:—

I. Craft lighter than air: "Aerostatic."
    1. Kites—
        Simple.
        Man-lifting kites.
        Balloon kites.
    2. Balloons—
        Captive.
        Free.
    3. Dirigible balloons—
        Non-rigid types.
        Semi-rigid types.
        Rigid types.
II. Craft heavier than air: "Aerodynamic."
    1. Aeroplanes—
        Monoplanes.
        Bi-planes.
    2. Helicopteres—
        Vertical lift machines.
    3. Combined dirigibles and aeroplanes.

While the main attention herein is given to dirigible balloons and to craft which are heavier than air, a few words may be said in passing with regard to the employment of kites and captive balloons, especially in warfare.

Kites.

Kites have been developed considerably in the British Army and Navy and on account of their cheapness and compact form for transportation, have produced very good results in the field. It appears that man-lifting kites have been very successfully operated from ships and lately Major Baden-Powell has worked out a system for using explosive kites against air ships. The man-lifting balloon kite, which is a combination of a small gas-bag and a second bag open freely to the air, has been developed considerably by the Germans, and has been used extensively in their manoeuvres.

Captive Balloons.

The captive balloon is, of course, familiar to all for purposes of general observation, signalling, directing gun fire and, recently, at sea, for the detection of submarine attack. It would appear that notwithstanding the rapid introduction of aeroplanes and dirigibles the captive balloon and kite will still remain a useful means of observation both on land and sea for some time to come.

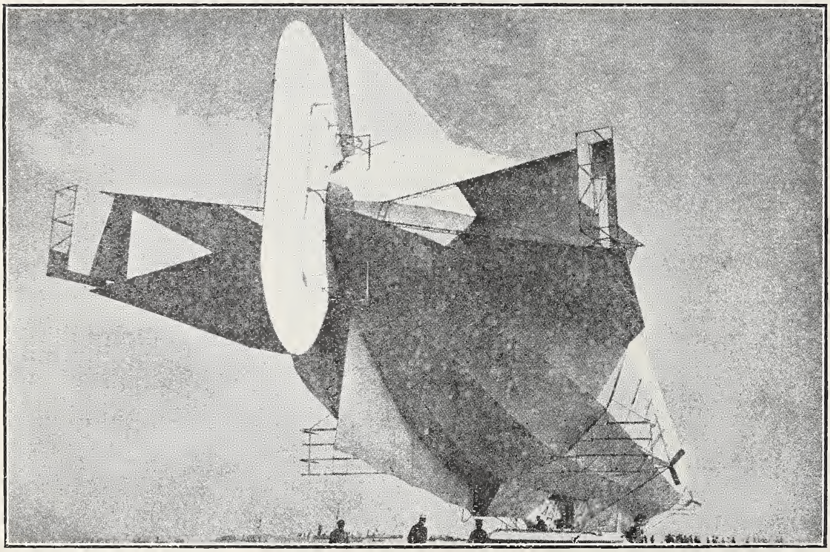
Dirigible Balloons.

Although many early attempts were made to propel balloons, no real success was made until the recent development of the light, but powerful automobile engine. After types of these engines became established their various applications to aerial navigation was most quickly taken advantage of with the recent remarkable results.

A German named Schwartz is credited with driving the first rigid airship with a gasoline motor, which was 12 h.p. His ship, however, was wrecked after several successful trials. This was in 1897. In 1898 Count Zeppelin came on the scene with a rigid type, having an aluminum frame and gas bags between an inner and outer envelope—built in gas-proof compartments as it were. It was a large vessel 300 feet long, driven with two gasoline motors, each geared to two propellers. Though he secured a still air speed of 16 miles per hour, there were many defects found and the attempt was temporarily given up, but patriotic Germans came forward in these discouraging days with money to build a second.

In 1902 Santos Dumont, in a non-rigid cigar-shaped balloon, performed the first really signal dirigible feat by circling around the Eiffel Tower in Paris, winning a prize of $20,000. This year also saw the first work of the Lebaudy brothers, who brought out a semi-rigid type by which the bending and buckling strains are taken off the gas envelope by a metallic keel; this was propelled by a 35 h.p. motor. This vessel was wrecked in 1903 after doing some 50 successful trips, the longest being 62 miles at 22 miles per hour average. But this was the start of the great French airship fleet, for shortly afterwards the French Army adopted a similar type, and after several successful ships, the "Patrie" was launched in 1906, and in 1907 was used in the manoeuvres, doing a trip from Paris to the frontier, a distance of 150 miles, at 22 miles per hour. Shortly after, however, the "Patrie" was wrenched from her moorings, blown away and lost on the North Atlantic. This was followed by the "Republique," the largest of the semi-rigid type yet built, having cylindrical stablizing gas bags at the stem; she was 210 feet long, had an 80 h.p. engine, a range of action of 500 miles and could carry nine men. In 1908 she did 147 miles at 21 miles per hour.

In the meantime Count Zeppelin had succeeded in his second ship, which was tested in 1906, but was wrecked by a storm. This was shortly followed by a third, and in 1908, by a fourth much more powerful than its predecessors. This "Zeppelin IV." was built on special specifications of carrying power, speed, endurance; she was 446 feet long, had two Mercedes motors of 120 h.p. each, carried a crew of 18 men, and her estimated range of action was 800 miles. One special feature was the arrangement of the 16 independent gas bags within the envelope. This airship was tried out in numerous preparatory short trips before the official government trial, by which the airship was to carry 16 men and be capable of travelling for 24 hours. In one of these trials in June, 1908, "Zeppelin IV." went across the Alps, doing in 12 hours a total of 270 miles at an average speed of 22 miles. In August of the same year an eventful attempt in which the ship again travelled a distance of 270 miles at an average of 24 miles per hour, resulted in its com-



ZEPPELIN IV. DIRIGIBLE BALLOON

Courtesy John Lane Co., from "Airships in Peace and War," *Hearne.*

plete wreck by explosion and fire; this accident could not have occurred, it is said, had there been apparatus for properly anchoring the vessel to the ground while at rest.

The same year two other successful German dirigible airships, the "Gross" and the "Parseval," both military ships, made their appearance, the former remaining aloft for 13 hours, and reaching an altitude of 4,000 feet, and the latter for 12 hours.

In 1909 dirigible airships of the foregoing types performed many successful and extraordinary flights. France put four notable new ships out—similar to the "Republique." The latter vessel, while going to the French Army manoeuvres, met with an accident which was promptly repaired by the Airship Corps of their army in the field under virtual war conditions. This field repair marked a new step in progress. The ship was used in the manoeuvres and did very useful intelligence work, particularly discovering a wide turning movement of its opponents. The "Republique" was completely wrecked by the breaking of a steel propeller blade in September, and the crew of four killed.

In Germany 1909 saw remarkable performances of the new Zeppelin's, the "Gross" and the "Parseval." The former made a round trip of 800 miles, including the sailing over Berlin, and this placed the Zeppelin far ahead of all rivals. The work of four airships at the German military manoeuvres that year was extensive, and though no information was given out it is known from attaches' reports that exceedingly useful work was accomplished. One interesting operation was a night attack against the fortress of Ehrenbreitstein on the Rhine near Coblenz, in which several ships were employed.

During the year 1909 a new Italian airship in a run of 190 miles made 27 miles per hour average, which captured the high speed record.

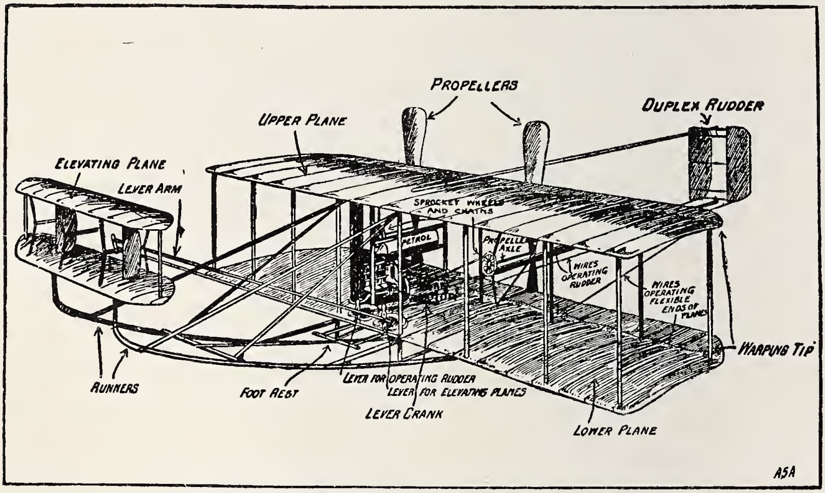
The year 1910 produced some new records of particular interest, and there were several notable flights of historic value. Wellman made a courageous attempt to cross the Atlantic, starting near Boston. His arrangement, which he called an "equilibrator," which dragged in the water to stabilize the ship, nearly caused a fatal ending; as it was, the ship was blown about and out of its course by a fierce gale, and was finally abandoned about 200 miles at sea, the crew being taken off by a steamer under thrilling circumstances. The French dirigible, "Clement Bayard II.," made a remarkable flight from Paris to London on October 16th, doing 246 miles at an average of 41 miles per hour, with a crew of seven men. This airship is 251 feet long, 44 feet diameter, has two engines of 120 h.p. each, a range of 750 miles, and carrying a capacity of 20 men.

Dirigibles were used in the principal European Army manoeuvres in 1910, with varying success. In this connection the great success of the British dirigible, the little "Beta," is of interest because of the plucky work of its commander. It is just announced that this airship, working near Aldershot this week, kept in touch by wireless during the whole of a trip of many miles from start to finish.

On February 7th, 1911, the German dirigible, "Gross IV.," was taken out for its first trial. It is 344 feet long and expected to be one of the fastest yet constructed, being capable of making 40 miles per hour. The British admiralty, however, has just now (February 18th) about completed a monster airship—the first aerial "Dreadnought"—at Barrow-in-Furness, 510 feet long, 48 feet diameter, and having 706,000 cubic feet capacity; eight cylinder motors, with three new type propellers are expected to drive the ship at 50 miles per hour.

Aeroplanes.

The perfecting and the employment of aeroplanes is much more recent than the similar progress with dirigible balloons. The early experimenting and research, however, commenced about 1892, and by 1896 there was considerable data and some experience accumulated with respect to bird-flight, gliding on air and laboratory aero-dynamics. The outstanding features of this period were the experiments with kites by Professor Langley in America, the construction of a steam-driven aeroplane by Sir Hiram Maxim in England, and the actual air-gliding by Lilienthal in Germany. With the latter's death and the great difficulties encountered by Maxim, progress almost ceased, and for a period of eight years the only work done was

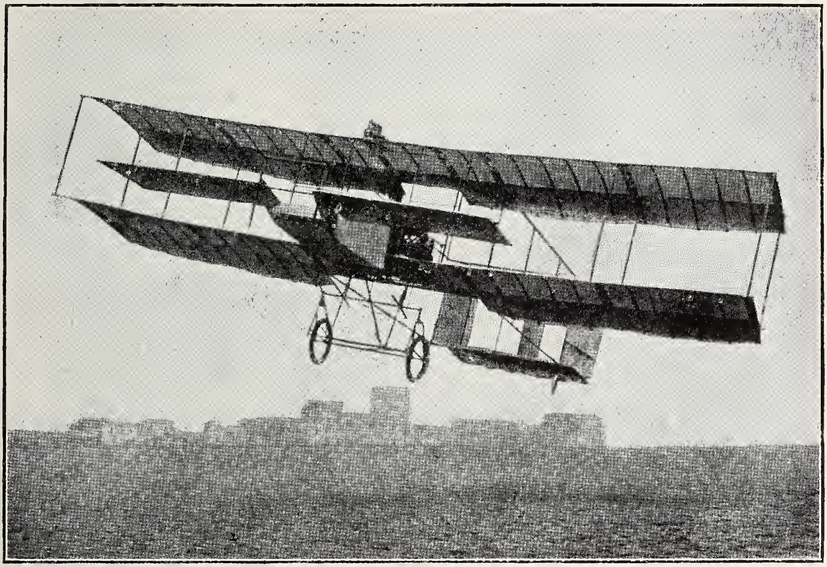


DIAGRAMMATIC VIEW OF WRIGHT BIPLANE

Courtesy John Lane Co., from "Airships in Peace and War," *Hearne.*

quiet experimenting in seeking after suitable engines, propellers and forms for aeroplanes. Chief among these workers were the Wright brothers, who, for some years prior to 1904, were working with one and two-plane gilders in North Carolina at a place where among rolling sand dunes a steady wind was assured. In this work they were assisted on the technical side by the late Mr. Octave Chanute, an eminent consulting engineer of Chicago. In such a manner they became expert in the handling of their air craft.

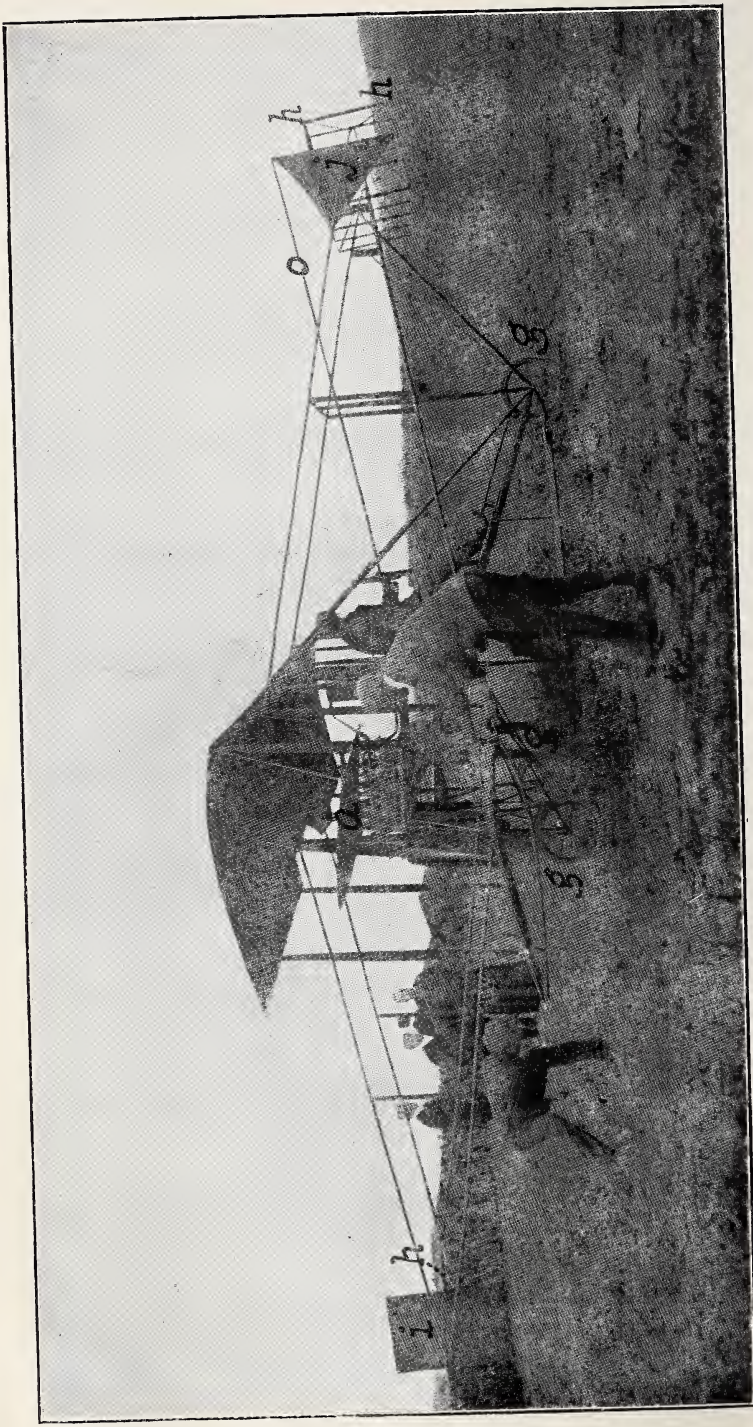
At this period —1905—several forms of aeroplanes had become notable, and with the solution of the engine problem following closely on the development of the automobile engine, actual flights were accomplished. There remained, however, the perfecting of innumerable details and the gaining of experience and skill on the part of operators to attain the confidence, presence of mind, and almost intuitive quickness necessary to control a heavier than air machine in much the same way as the learning to ride a bicycle. These early experiments of either gliding or driving a plane against the air for a short distance were based upon the principles of soaring bird-flight or of the skater on thin ice.



FARMAN BIPLANE

Courtesy Crosby, Lockwood & Son, from "The Art of Aviation," *Brewer*.

In 1905 the Wrights astonished the world with the announcement, without details, that their bi-plane machine had actually remained in the air for a half-hour, and later that they



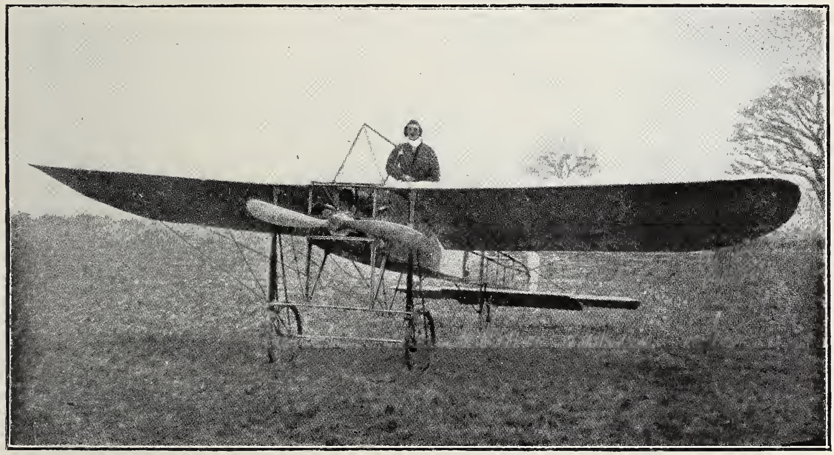
CURTISS BIPLANE USED BY J. A. MCCURDY, '07, (TORONTO)

Courtesy The Copp, Clark Co., from "Vehicles of the Air," *Longheed.*

had flown 24 miles in 38 minutes. In other flights they had attained great speed, the greatest having been 38 miles per hour.

As the Wrights undoubtedly led the world in the development and operation of their aeroplane, there are several features of the machine deserving of special mention here. The frame was of hickory and the planes of strong fabric; the wing warping device on the corners of the planes, worked by wires over pulleys for balancing and facilitating turning, were especially novel. This flexure of planes in conjunction with vertical and horizontal rudders enabled the balance to be quickly —almost instinctively—made. By their long experience in these early days the Wrights became so dexterous that they were for some years far ahead of other aviators in their skill in flying. They showed that it was more in the man than in the machine that success lay.

In 1907 a new aviator, Farman, appeared in France, and he accomplished numerous short flights, up to a half-mile, in a bi-plane, known then as the "Voisin." His performances, however, were soon eclipsed by those of Delagrange, another Frenchman, who, in 1908, flew various distances up to 15 miles, done on September 6th. But this month of September, 1908, was destined to become notable in aviation, as the Wrights, one in Europe, and one at Fort Meyer, in the United States, were almost daily performing something new, the one breaking the record of the other. The performances comprised flights of over an hour by Orville Wright in America on September 9th and 12th; in the latter 45 miles were covered. Wilbur Wright in Europe on September 21st, flew one hour and a half, in



BLERIOT MONOPLANE

Courtesy Crosby, Lockwood & Son, from "The Art of Aviation," *Brewer*.

which 56 miles were done and on September 28th, he carried a passenger.

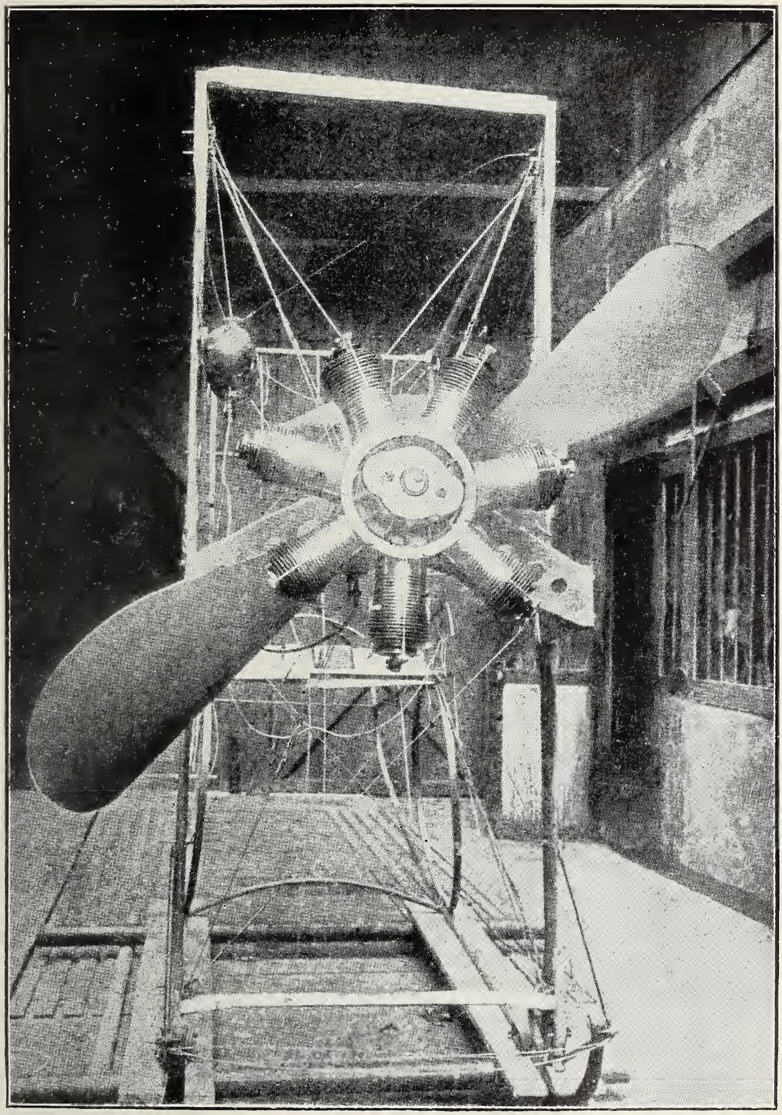
In October of 1908 Wilbur Wright, with a passenger, did 36 miles in 56 minutes, and Bleriot first appeared with his small monoplane, in which he did 3 miles in four minutes and a half.

The year 1909 was notable in aeroplane performances as well as for dirigible balloons. Orville Wright carried a passenger 45 miles in one hour and thirteen minutes on July 22nd, and three days later the world was startled by the news that Bleriot had boldly crossed the English Channel in a small monoplane, 31 miles in 40 minutes. Then on August 26th, Latham, a new aviator, with an Antionette monoplane, flew 97 miles in 2 hours and 13 minutes, and the following day Farman, again to the front, with his bi-plane, broke all records by going 112 miles without a stop. Again on November 3rd, 1909, Farman in his own bi-plane with a Gnome motor, flew 145 miles in 4 hours and 18 minutes. Another significant performance by Farman was on August 28th, when he carried two passengers 6 miles in ten and a half minutes.

This year a second American aviator came prominently before the world; this was Curtiss who, in a bi-plane of his own design performed various feats, especially at the time of the Fulton celebration at New York. His machine, developed with the advice of Dr. Graham Bell, is, in general, similar to the Wrights, but instead of warping the ends of planes, he has small auxiliary planes at the outside ends between the two main ones; his manipulation is also interesting, as he employs the shoulders and swaying body in actuating the rudders for horizontal turning. It is in this type of machine (perfected in the Hammondsport Experiments) that J. A. D. McCurdy, of the class of 1907, Engineering, in Toronto University, is now doing such wonderful feats.

The year 1910 did not produce any extraordinarily long flights, but the altitude records were very much increased, about 7,000 feet being the highest. The various aviation meets, notably those at Belmont Park and Atlantic City, brought out results in control and handling of aeroplanes which prove beyond doubt that these machines are capable of various rapid manoeuvres far beyond the earlier expectations, and these are probably only the beginnings, so that we are justified in expecting wonderful results in stability, manoeuvre and carrying power within the next five years. Speeds were also much increased, especially with the monoplanes which are, of course, the fastest types; Morane, with a new Bleriot, flew 66 miles per hour at Rheims.

As examples of manoeuvre in 1910 two performances in America are notable. One was by Graham White, an English aviator, who flew over the City of Washington, alighted in the street in front of the Navy Headquarters Building, made a call and rose again from the street and flew away again over the city. The other was at Belmont Park, when an aviator, off to a false start on the race course, was recalled and suddenly

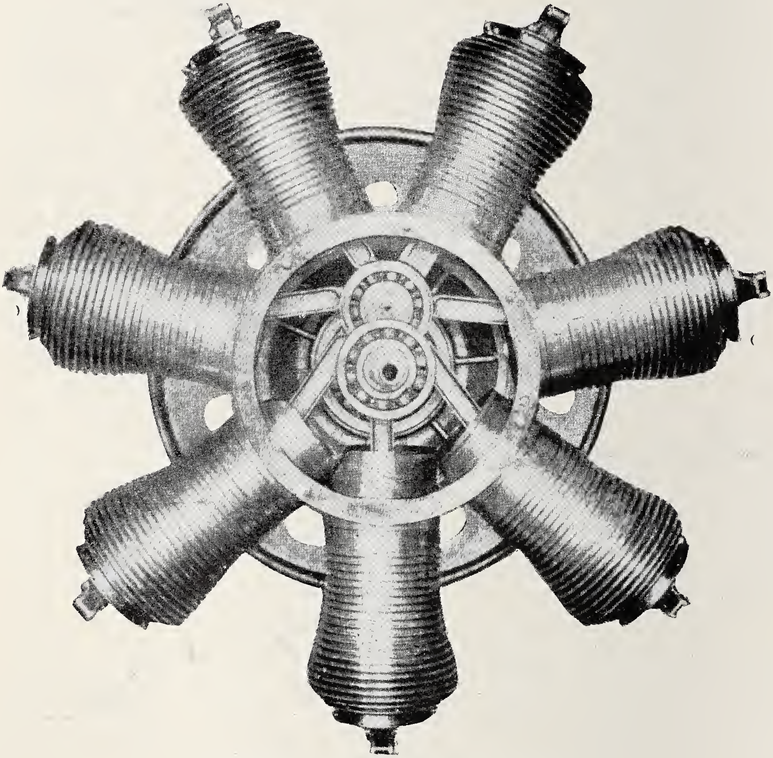


GNOME ENGINE AND PROPELLER
(THE WHOLE REVOLVES AS A FLYWHEEL)
Courtesy Crosby, Lockwood & Son, from "The Art of Aviation," *Brewer.*

circled in a small radius around the judges and the announcement board, back to the track in front of the grand stand.

The flight of Chavez in a Bleriot monoplane over the Alps from Switzerland to Italy in September, 1910, is also notable with respect to manoeuvre, as in 25 miles and a rise of 3,000 feet, he encountered all kinds of vertical cross air currents and bitterly cold air off the snow-clad peaks.

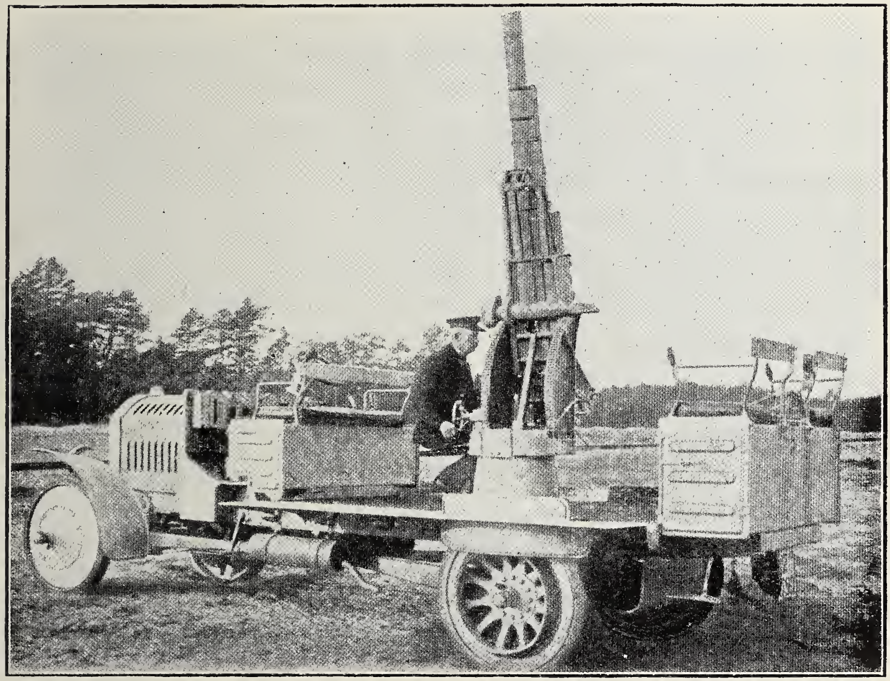
It is likely that the next few years will produce aeroplanes of much greater carrying power as well as of greater manoeuvring capabilities. Increases of speeds are also to be expected, especially with the monoplanes. It was announced in 1910 that a new racing Bleriot had been built and was being secretly tried, in which speeds up to 75 miles per hour were expected. This type had ingenious wings, which could be flattened out in mid-air and contracted so that the machine could be speeded up while actually in flight.



INTERIOR OF GNOME ENGINE
Courtesy Crosby, Lockwood & Son, from "The Art of Aviation," *Brewer.*

Combination Types of Airships.

There is not much yet to be said respecting airships combining the features of balloons and aeroplanes. Several such arrangements have been built and tried, but not worked out over long courses. Vertical lifting machines have also been built, but as yet have not become practical. It is likely, however, that considerable progress will be made within the next few years along the combined lines, especially for meeting conditions where ascents and flights are required to be made irrespective of weather conditions, such as may be absolutely necessary in warfare.



GERMAN 3-INCH GUN FOR ATTACKING AIRSHIPS
Courtesy Crosby, Lockwood & Son, from "The Art of Aviation," *Brewer.*

There is no doubt that very shortly a vertical lifting "heavier than air" machine will be brought out, capable of standing stationary, or hovering over any point; this will probably combine the horizontal speed properties of the aeroplane.

A new combination of airship and hydro-plane is also beginning to appear, brought about by the necessity of aeroplanes alighting on or rising from water. Only last month Curtiss, in such a machine at San Diego, Cal., alighted on the water alongside a U. S. warship, and after 15 minutes' visit, rose again from the same spot.

Feasibility of Aerial Navigation.

From the foregoing it is not only apparent that the navigation of the air is feasible by dirigibles and aeroplanes, but that as each year passes, with its improvements in types and increased skill in handling, aerial navigation will, before long, be as assured, and as universal as motoring on land or water. It is now only a question of a few years before dirigibles carrying cargoes of many tons, and aeroplanes carrying four or five people will be an established thing. The science will be then beyond the experimental stage and there will be many operators of all nationalities having the requisite experience and skill to actually navigate the air with ease, confidence and safety.

In view of the present state of the building and skill in flying, we are reasonably justified in expecting that in the next two years:—

Dirigible balloons will have a range of action of 1,000 miles, a speed of 40 miles per hour, and a carrying capacity of 4 tons.

Aeroplanes will have a range of action of 200 miles, a speed of 50 miles per hour, and a carrying capacity of 800 pounds.

Both classes of air craft will be capable of operation at will in any moderate wind, either with or against it.

If the foregoing results can be realized the successful permanent employment of such dirigible balloons and aeroplanes for military purposes is an absolute certainty because they are then brought into the category of practical fighting equipment of modern armies and marine navies.

Employment of Airships.

It is as yet premature to attempt any serious conjecture with regard to the ultimate employment of air-craft, either in extent or variety. While commercial uses may appear probable within the next few years military uses are already in sight and a discussion of the possible employment of air-craft for this purpose would be of interest.

Already, as noted, the great powers have been employing dirigibles and aeroplanes in connection with both army and navy manoeuvres. Just now comes the news that Germany will, in the 1911 manoeuvres to be held on the Baltic coast, use flying machines in connection with combined operations in which the battleship fleet will co-operate with their army corps in problems involving the landing of an army in coastal defence.

In those features of modern war, involving tactics and strategy, the employment of air-craft will entirely revolutionize the science. The application of mounted reconnaissance for both tactical and strategical purposes can be applied equally well to aerial scouting with the addition that the range of action and the horizon will be very much increased.

The peculiar adaptation of dirigible balloons and aeroplanes is very marked; a few of these properties, especially for war operations, are as follows:—

1. Wide range of action is now obtainable.

2. Carrying capacity is sufficient for men and food, etc.

3. Speed is as fast as any land or sea travel without delays occasioned by latter.

4. Height of operation is such as to be clear of accurate effective gun fire.

5. Direct routes are available day or night, or in fogs (within limits).

6. Positions of altitude are most adapted for observation and signalling, and for locating submarine objects.

7. Air operations cannot be guarded against except with similar craft or by special terrestrial apparatus.

In adapting these various proven properties of airships and especially of aeroplanes, there are certain well-known uses which have already become apparent for military and general service; an enumeration of these follows:—

For Military Service.

1. Peace and war time reconnaissance, reporting and study of foreign countries, fortifications, harbors, etc.

2. Signalling and wireless telegraph purposes.

3. Carrying despatches.

4. Guards and patrols at frontiers and before an army.

5. Preventing an enemy's observation and screening operations from view.

6. Directing and observing artillery fire.

7. Destroying stores and raiding harbors, fortresses and cities.

8. Surprise or night attacks.

9. Discovering and destroying submarines and mines.

10. In conjunction with general engagements on land or sea.

For Commercial Service.

11. Despatch carrying for emergency purposes.

12. Rapid express transport or mail service.

13. Passenger service of rapid and luxurious character.

14. Exploration in inaccessible or far-distant countries.

15. Scientific research.

16. Rescue purposes at sea.

17. Recreation, sporting and spectacular.

The commercial use of aeroplanes, for instance, while as yet conjectural, affords quite as much variety and opportunity for development in types and their employment as does the military use. It must be remembered, however, that in order to adapt air-craft to commercial use they must meet the powerful competition of the present forms of land travel and the opposition of those commercial organizations operating the land and water transportation utilities. On the other hand, because of the fact that all aerial travel can be made on routes direct and unhampered, and that travel routes have three dimensions in which to operate, the ultimate success of aerial navigation can be fully expected though it may take a stretch of the imagination at present.

As a case in point illustrating commercial use the following comparison in time of the employment of an aeroplane in competition with a railway train, and a motor car, is suggested, it being assumed that a doctor in London is suddenly called upon to make a special emergency call in the country 100 miles distant by bee-line, 120 miles distant by rail, with nearest station four miles, and 140 miles by road. This outline is an extract from "Airships in Peace and in War," by R. P. Hearne:—

SPECIAL TRAIN		SPECIAL MOTOR CAR		SPECIAL AEROPLANE	
Getting ready	30	Getting ready	10	Getting ready	15
Passengers' time to starting point	15	Journey to doctor's door	15	Passengers' time to starting point	15
Time getting clear of London	10	Delay in getting clear of London	35		
120 miles at 50 miles per hour	145	130 miles at 35 miles per hour	222	100 miles at 60 miles per hour	100
From station to house	20	Delay in getting to house	8	Landing and getting to house	20
Minutes	220	Minutes	290	Minutes	150

Operation of Air-Craft.

As to the probable methods of operation of the various types of airships much can be said and conjectured, but until a good many features of endurance, reliability, speed and handling are tried out, it is not likely that definite conclusions can be reached. Even with the more stable types of airship, and in the short years of trial up to the present, the accidents which occurred, and the loss of life, have been appalling. In the year 1910 the number of famous aviators who have lost their lives has been most deplorable, but unfortunately it is to be reasonably expected that there will be still many more accidents and loss of life in the strife for the mastery of the air before the art of building ships and flying them will become fixed like other similar operations. As, in the nature of events, the "heavier than air" machine is undoubtedly destined to become the ultimate means of aerial locomotion, it is evident that in its development there must yet be years of trial, success and failure before final definite success is attained.

The various difficulties and dangers which have already been encountered are really at the present time increasing rather than being reduced, for as the art advances and navigators become bolder, the hazards taken are greater. For instance, at one time it was thought that navigation in wind and rain storms, fogs, etc., was impossible; now we find ascents being frequently made under such weather conditions, as, for example, when Latham in 1909 went 75 miles per hour in a gale at Blackpool in his Antoinette monoplane. Fires and explosions on dirigible balloons are a great menace—instance the disaster to Zeppelin IV.—possibly lightning would come also in this category. Breakdown of engine or of propellers or steering gear, etc., in aeroplanes is almost fatal, especially in high flying unless the aviator is successful in righting the machine and gliding to earth without overturning; nearly all fatal aeroplane accidents have been due to this mishap though ehere are several notable examples of the machine being brought down safely—instance, Curtiss at Atlantic City in 1910. Loss of fuel either by leakage, accident or use is another danger. Collision with buildings, trees or other craft is also to be reckoned with.

Organization and Training of Aerial Corps.

It is not at all surprising that, with all this progress and the swift application of aerial navigation to uses of warfare as the first employment, the nations are seriously organizing and training aerial corps. Next to the development of the machine and equipment, the training of experienced expert aviators and aeronauts is paramount. This is harder than it seems for the means of training are limited, are highly expensive, and often produce discouraging results, as have been experienced the past 3 years. The present year, however, sees all the great powers appropriating large sums in their estimates for this purpose. The German Government has planned very large expenditures, and it is now unofficially announced that eleven German universities will, during the summer of 1911, institute lectures on aeronautics and the mechanical principles underlying the flying machine and its operation. The United States has authorized very considerable expenditures in training, and the news just comes that the National Guard of California has authorized the formation of an aerial corps in connection with the Coast Artillery. It is interesting to notice that the British Army estimates for 1911 include a half-million dollars for new dirigibles and aeroplanes and for the expenses of an aeronautic staff. It is stated in newspaper despatches that the British Army will have five dirigible balloons and five aeroplanes available for use the coming summer.

As to training, especially in aeroplane operation, the work of Mr. Curtiss at San Francisco for the U. S. Army and Navy is of special note, as indicating how he instructs novices to handle a machine. The first operation after mastering the mechanism of machine and engine is to take short hops or jumps of from 50 to 200 feet, but not higher than 20 feet. Then longer jumps are allowed, and then a low flight, skimming the surface or "grass-cutting" as it is called. After this recruits are allowed to fly and manoeuvre, but always over level ground and close to it. Reports say that practical and athletic officers who are accustomed to motoring and sailing learn very rapidly and safely.

Toronto, March 1st, 1911.

DETAILS OF AEROPLANE TYPES

(As in use in 1909 and 1910.)

CHARACTERISTICS	MONOPLANES		BIPLANES			
	BLERIOT	ANTIONETTE	WRIGHT	FARMAN	VOISIN	CURTISS
AEROPLANES:—						
Span, feet	28	46	40	33	38	29
Area, sq.ft.	150	377	540	430	540	250
WEIGHT:—(No Pilot)						
Total, pounds	462	1045	880	990	1100	550
Per sq.ft. of Plane	3.08	2.77	1.63	2.30	2.04	2.20
MOTOR:—						
Type—Cylinders	3	8	4	4	8	8
Revs. per min.	1200	1100	1500	1300	1200	1200
Power in H.P.	24	50	30	50	50	30
Sq.ft. Area per H.P.	6.25	7.50	18.0	8.6	10.8	8.3
Weight per H.P. per sq. ft. Area	0.13	00.5	0.05	0.04	0.04	0.07
PROPELLER:—						
No. of blades	2	2	2 of 2	2	2	2
Material	wood	steel	wood	wood	steel	steel
Diameter	6ft. 9in.	7ft.0in.	8ft.0in.	8ft.6in.	8ft.6in.	6ft.0in.
Speed	1200	1100	450	1300	1200	1200
SPEED:—						
Miles per hour in still air: Average	40	38	39	41	37	48

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IMPRESSIONS OF ENGINEERING IN GREAT BRITAIN.

CHESTER B. HAMILTON, JR., B. A. Sc.

The Institution of Mechanical Engineers, whose headquarters are in London, England, last year invited the American Society of Mechanical Engineers to hold a joint meeting with them, during the last week of July, 1910.

The official party of the American society, numbering about 150, left New York on the White Star liner "Celtic," on July 16th, while about as many more went earlier.

We arrived in Liverpool on the evening of July 24th, and were met at the mouth of the Mersey by a tender, which brought out a deputation from the Lord Mayor of Liverpool, and from the Institution of Mechanical Engineers.

From that point on the time was so crowded with engineering and social opportunities that it made one wish that there were at least forty-eight hours in the day. Our English friends certainly are the kindest of hosts. The convention lasted a week, first at Birmingham, then at London, stopping over a day on the way at different points of interest. All the numerous side excursions throughout the week were arranged so that people of the most varied tastes might choose according to their preferences, and thus everyone might be satisfied.

The convention closed Sunday evening, with a visit to Westminster Abbey, around which we were conducted by the sub-Dean. The engineers were particularly interested in the memorial window to Sir Benjamin Baker, the builder of the Forth Bridge and the Assouan Dam.

The following day the party began to break up, the members going where the greatest interest drew them. The writer went to Holland and Belgium and the Brussels Exposition; then returned to England, visiting as many engineering and manufacturing plants as possible, and finally took a short trip to Scotland.

In general it may be said that in all matters touching on either the navy or merchant marine, one may look for the highest efficiency in British works or factories.

The new Yarrow shops on the Clyde, building torpedo boats and destroyers, are an example. They are not very large, compared to some of the other great works, but they are as good shops as I have ever seen—high, well lighted and ventilated, good crane service, and general orderly arrangement. One of the features is a roofed-over "water-dock" (this name being used in distinction to a dry-dock), equipped with electric traveling cranes, under which the destroyers are fitted up after launching. Only turbine engines are now used, along with the famous Yarrow watertube boilers. It was rather a surprise to see them building destroyers for Holland—a maritime nation itself. They were also at work on boats for Denmark and Brazil. These latter are taken to Brazil by their own black and mulatto crews, but the Yarrow's send one or more engineers from their shops to insure their arrival, which otherwise might be doubtful.

At Cathcart, a suburb of Glasgow, I visited the Wier Pump Works. They build only direct acting steam pumps of very high grade, principally for marine use. This is another first class shop, with both its general methods and details more carefully worked out than usual. The principal part of the shop is one storey with saw-tooth roof. A line shaft down each row of columns drives the machines in that bay; power is supplied by a horizontal single cylinder gas engine at the end of each bay, using producer gas. Thus they get most of the advantages of group drive, as the number of machines on each shaft is small; and also get very cheap power and high efficiency, for the transmission is short and direct. There are almost no motor drives in this shop. They have little to gain, and the management fears the expense for maintenance of 1,500 small motors. They use a large number of Reeves' variable speed friction gears, where an electrically driven shop would use interpole motors, and by fine adjustment of the speed of the machines are able to get the highest efficiency from the tools. They like the Reeves gear very much, and are applying it to most of their new tools.

A large number of their machine tools are made especially for the job for which they are intended, thus they are simpler, more rigid and accurate, and sometimes cheaper than standard tools, as they do away with unnecessary adjustments, slides, and universal features.

They have a very good foundry for admiralty bronze, where they do first class work. They are under the difficulty of having to use very poor, almost gravelly moulding sand. They have a good system of standardized flasks and large patterns, divided into sections the same length as the depth of one section of the flask. In this way the mould can be given to a number of different men to finish at the same time, thus making greater speed possible. Every convenience is supplied the men to enable them to turn out high grade work efficiently. This foundry was a great contrast to one in Birmingham, making builders' hardware by most antiquated methods. I account for this by the fact that the Birmingham firm were not doing marine work. The Wier Pump Co.'s methods evidently pay, for they claim, with apparent right, to be the busiest shop in Great Britain, employ 2,000 to 2,500 men under good working conditions, and are putting up additions to their shop, while some other people are struggling to keep out of the receiver's hands.

The Vickers Maxim Co. and the Sir Wm. Armstrong, Whitworth Co. are two of the largest iron-working firms in the world. They both make almost everything, but, of course, specialize in work that is too big for other firms.

One of our party was talking to Mr. Matthews, the managing director of the Armstrong, Whitworth Company, without knowing who he was, and asked him what line he manufactured. He replied: "Oh, anything you like," adding in explanation, "anything from a ten-penny nail to a fully equipped battleship."

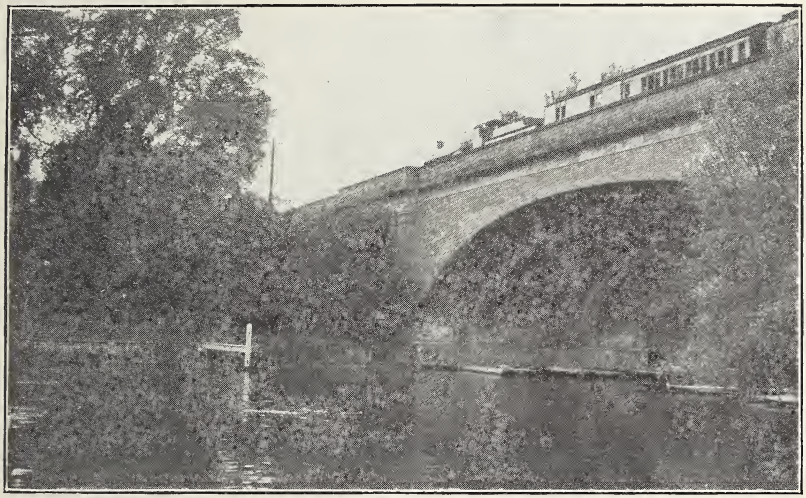


Fig. 1 Brick Arch Railway Bridge on the Thames.

In the Whitworth shops I saw a very large and heavy engine lathe, specially built for another company, to machine the parts of large marine steam turbines. This lathe was large enough to swing a small room over the ways, and so heavy that the ground in the purchaser's shop would not support it, and shipment had been delayed till another site could be found. Another machine tool not seen in this country is the armor plate shaper. These machines somewhat resemble a radial drill (on much larger scale, of course), having a very long arm with an auxiliary support at its end. The tool carriage slides on the horizontal ways on the arm (like the drill head), and is driven by a multiple thread lead screw of rather long pitch. A double tool is used, so that a cut is taken on both forward and return strokes. The machine is used for cutting armor plate and finishing the edges. Such great works as these have facilities for setting up in the shop the complete side armor of a battleship, to insure its accuracy of fit before it is sent to the shipyard.

In the Whitworth shops there are almost no automatic machines. They use a large number of boys on cheap lathes on work that could probably be better done on a screw machine. They do this in order to train up a sufficient supply of good lathe hands. This question of an extensive apprenticeship system versus automatic tools seems to be one of the weak points of the American method, which tends to produce a shortage of really skilled mechanics.

At the Vickers Maxim shops I noted the remarkable way in which government work is done in an open shop and yet kept secret. I saw many parts of H. M. S. "Lion" and another ship of the super-Dreadnought type, and was told that the information that such a ship was being built had only become known after practically all her parts had been completed.

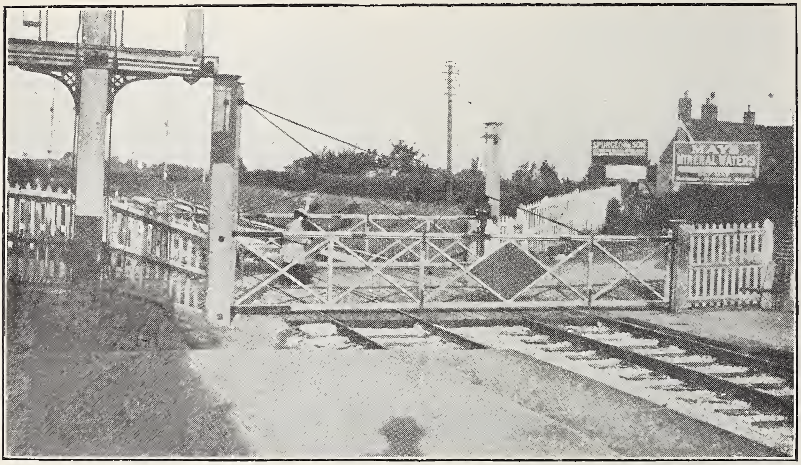


Fig. 2. Crossing Gates on an English Railway.

At Wier's Pump Works, at Glasgow, I was shown the condenser pumps of a great ship, which they were forbidden by the purchaser to speak of except by its shop-order number. The jealousy between rival trans-Atlantic steamship companies assists in the maintenance of secrecy, for no one could tell whether these pumps were for a Cunard or White Star ocean greyhound or a British or a Brazilian Dreadnought, though it was evident to anyone that they belonged to a record-breaking engine-room equipment.

It is extremely difficult to keep any secrets now that Japanese inspectors on Japanese Government work are in the shops, for they go everywhere with sharp eyes and notebooks. Vickers used to build complete ships for the Japanese. They made the guns for their latest Dreadnoughts, but the Japanese are building the ships themselves. Soon the Jap will be making guns and all.

A rather interesting machine tool is in use at Vickers (and probably elsewhere) for cutting the portholes in armor plate and for boring out large ingots and forgings preparatory to hollow-forging them on a mandril for the parts of heavy guns. Its action is quite analagous, but on a much larger scale, to a diamond rock drill. The boring bar is hollow and carries a series of cutters arranged around the end so as to cut out an annular channel and leave a large core, thus effecting a large saving of time and power.

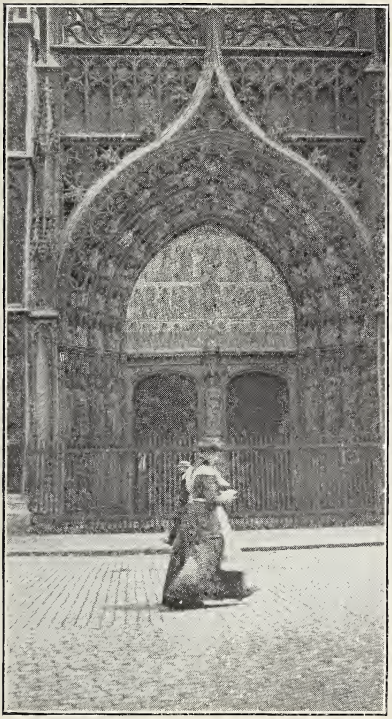


Fig. 3. Entrance to the Cathedral, Antwerp.

Fig. 4. Motor Busses, Trafalgar Square, London.

These great shops, Vickers, Maxim's and Armstrong, Whitworth's, are too big for appreciation or comparison by any standards we have in Canada.

Reference was made above to a foundry in Birmingham, where very poor methods were in use, both mechanically and in the treatment of the employees. A considerable proportion of the latter were women and children, who were working under "sweat-shop" conditions. This place, I understand, was typical of many others. Piece work was the rule, and the rate was so low that they had to work in desperate haste for long hours to earn very small wages.

Malleable iron castings were being made in small crucibles (60 to 100 lbs.) The moulders worked in groups of three under a contract system in little half-open sheds around the side of the yard. No moulding machines were used. None of the patterns were carded, all being in loose pieces, and the moulder had to cut the gates for every little piece, weighing, perhaps, only a few ounces, every time it was moulded. In the electro-plating room there was no efficient ventilation. The operators, who were young girls, were working in a choking atmosphere. What little machining there was on this class of work was done by child and female labor, in a half-lighted basement, with poor tools and, as always, at extreme speed.

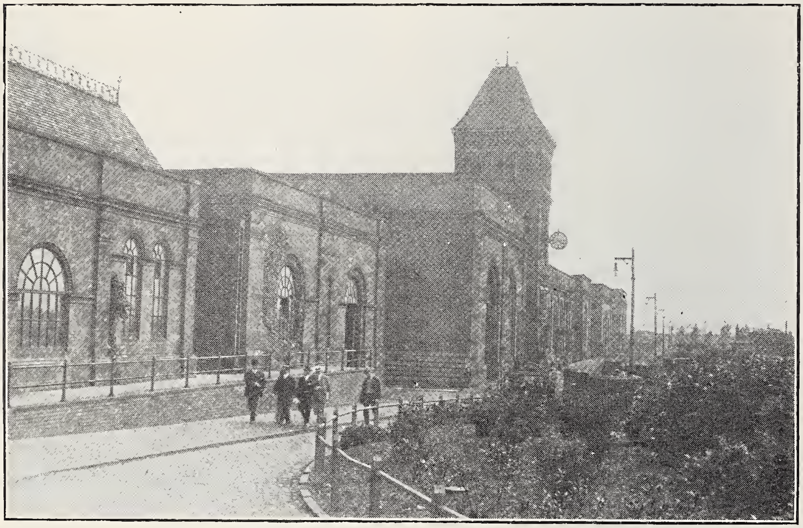


Fig. 5. Willans & Robinson's Engineering Works, Rugby,

In going through the factory districts there was opportunity to observe much more of the poverty of the country than is seen by the ordinary tourist. And it is not the poverty of hard times or accidental misfortune, but a deep, hopeless state, from which there seems no escape. What encouragement can these "submerged" ones take from the news that the Ontario manufacturer, the Manitoba wheat farmer, and the new Transcontinental railways are in need of labor? None, for that is on the other side of the world, and, besides, many of them are mentally and physically unfitted by heredity and environment.

One impression of the whole country is that it is a land where people and human effort and human suffering is cheap and material is expensive, in contra-distinction to America, where raw material is cheap and people are relatively more important. In Holland and Belgium dogs are much used for light draught. One American engineer said: "This is a fine country, but I'd hate to be a dog here." So I would say that England is a great and wonderful country, but I'd hate to be a laborer or mechanic there. I thought many times of Goldsmith's lines in "The Deserted Village":

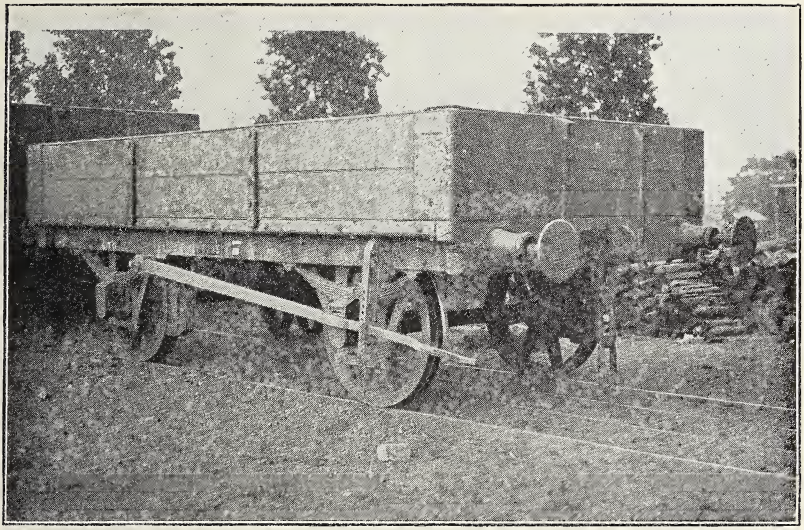


Fig. 6. English Goods Truck.

> "But a bold peasantry, their country's pride,
> When once destroyed, can never be supplied."

Messrs. Webley and Scott occupy, for the manufacture of revolvers and automatic pistols, a rather old, crowded, and badly arranged building, and the speed of production is high, but the quality of their output is of the highest, and the workpeople seem intelligent and comfortable. Is the explanation of this that theirs is the trade of the armorer, which, with its companion, the shipbuilder, holds such a premier position in Britain? In this large shop there was not a drawing or a scale to be seen, outside the tool room, everything being made to standard jigs and gauges.

The illustration of the Willans and Robinson shop, at Rugby, shows the handsome building and the fine gardens and shrubbery about it. The works are arranged so they can be enlarged to double the present size by extending sideways without disturbing any of the departments. All this reserve is given to the workman for garden plots. A large and elaborate testing plant has been provided, adjoining the power house, and connected to the rest of the works by a three-foot gauge railway system. Here careful tests can be made on engines, turbines, and pumps under almost service conditions, before shipment. The departments in the remainder of the works are conveniently arranged in series, as follows, from rear to front: Pattern storage, foundry, casting storage, forge and machine shops, erecting bays, packing and forwarding department, pattern shop, and office. It will be noted that, with the exception of the pattern shop and office, this is the logical order in which work would pass through the shops.

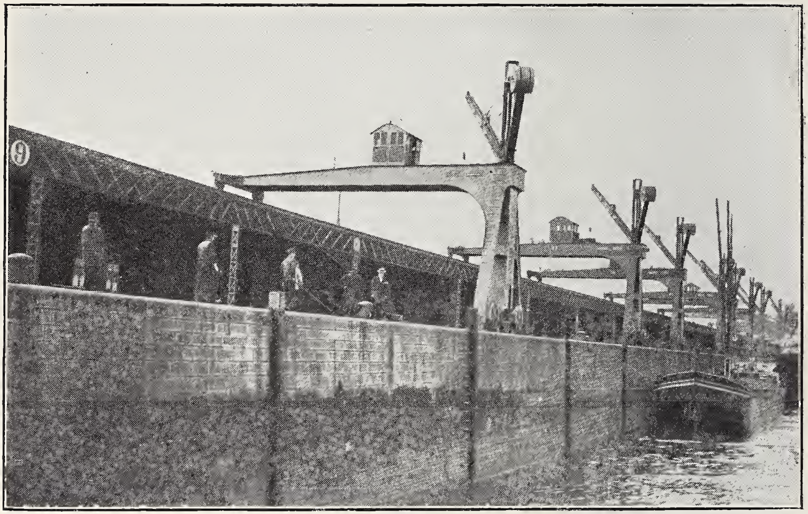


Fig. 7. The Dock Cranes at Antwerp.

The famous Willans engines were formerly made here in large numbers, but of late the principal output of this company has been steam turbines, Diesel engines, turbine pumps, and condenser apparatus.

Traveling so much away from the beaten track of the tourists gave a good opportunity to compare European with American methods of handling passengers. To be quite frank, they were generally not such as to excite admiration. We have all heard how the pirates used to make their victims "walk the plank." A modern repetition of this may be seen in the method of unloading second and third-class passengers at Queenstown, which resembles also the way cattle are handled at the large packing houses. Rain, wind, and the hour of 3 a.m., all added to the situation. The "victims" were compelled to carry their own hand-baggage, which averaged more than two pieces per person, down a long, narrow, slippery gang-plank, poorly provided with cleats and rails, at a slope of between 40 deg. and 45 deg. One end of the plank swung with the motion of the ship, and the other with that of the tender, which was to take the passengers ashore.

English trains accelerate more rapidly than our heavy American rolling stock. In view of this it was a real disappointment one day to find that a train which was already half-way out of the station could be overtaken and boarded. The fact that a fine or imprisonment is provided for boarding a train in motion was not known then.

In the eyes of an American the compartment system is altogether objectionable. The best trains now are constructed on the corridor plan, but they are so narrow that they are not in the same class as American coaches. The complete absence of any baggage checking system is a very bad feature of English travel. The responsibility rests entirely on the passenger to see that his baggage arrives at the same place and time as himself. In this connection it was necessary to use the long distance telephone several times, and I found both the service and the clearness of transmission far below what would be tolerated in American or Canadian practice. Telephones are not used in England to anything even approaching the extent they are in this country.

Fig. 8. Working on the Dykes, Holland.

English express trains are equipped with the Vacuum brake, but many passenger cars and all freight cars are without brakes. The illustration shows an arrangement, which is called a brake, used only for holding a freight car on a siding. Some freight locomotives have only hand brakes. Automatic couplers are unknown, the three chain links being universally used. On passenger equipment the middle link screws up like a turnbuckle, drawing the cars together and compressing the spring buffers. This makes the train very smooth in starting. In coupling cars an implement called a coupling hook is used which resembles a garden hoe with the wide blade cut off and the iron spike twisted like three-quarters of a turn of a corkscrew. Thus a man need not go between the cars—provided he has a hook with him.

One advantage, however, of the great amount of slack in a train of such cars is that less tractive effort is required to start from rest a train of these than one of equal tonnage of close-coupled cars. Consequently English locomotives are light, particularly as to weight on the drivers, compared with American engines. It seems that this, along with the light weight of the cars is the real reason for the smooth roadbeds of the English railways. Great pains are taken in building the roadbeds, which certainly reduces the maintenance cost, but it is doubtful whether they would stand the extreme hard usage to which American roadbeds are subjected much better than ours do.

Fig. 9. Dutch Windmill.

The oddity of shipping merchandise, often perishable, in open "goods trucks," covered only with tarpaulins, strikes the Canadian visitor strongly. These "goods trucks" and "goods vans" are exactly like the pictures in an old book I have which was published over thirty years ago. Apparently there has been no substantial change or improvement in this rolling stock in the last thirty or forty years. The ordinary goods truck is ten or twelve feet long over all, and carries ten or twelve long tons. To ship a sixteen-foot board requires two cars, unless it can be arranged to overhang the next load. The small size of the standard tunnels is one of the great obstacles to the English railways.

After all, no matter how far the English railway falls short of American and Canadian standards and requirements, we must remember that it fills the English requirements satisfactorily, and carries the inland traffic of a great nation with greater speed and safety than is the case with American or Canadian railways.

Figure 2 shows an arrangement of crossing gates, which affords great safety, but could probably not be applied in a country having much snow.

American locomotives have been tried in England, but have been found unsatisfactory. The material and workmanship are both much inferior to those in English engines. English engines all have solid copper fireboxes, and many have copper tubes. The English idea seems to be to make machinery as good as possible, whether it is economically worth while or not, while the American way inclines toward building only to last till the time when the design will probably be out of date. Each method suits the conditions of the respective countries.

In urban traffic the horse is rapidly disappearing. The taxicab replaces the hansom and the motor-bus its horse-drawn predecessor. The type of motor-bus used in London is shown in the photograph of Trafalgar Square.

Figure 1 shows a brick arch railway bridge of very good design. This compares favorably with some of the recent reinforced concrete arches. The centre span of this bridge is said to be the longest brick arch in Great Britain.

It was said that the only important features in Antwerpt were the cathedral and the method of handling freight on the docks with gantry cranes. Whether this is true or not I cannot say, but these two items at least are worthy of the admiration of the architect and the transportation engineer.

Figure 8 shows a rather inefficient but very industrious application of hand labor to the making of additional land on the Zuider Zee, in Holland. The material is dredged up from the bottom of the sea, some sixteen feet, and filled in between the old dyke and a new one (not shown), thus making one more farm.

There is, on a trip like this, an almost unlimited opportunity for American engineers to observe new and useful methods, and we were all deeply grateful to the Institution of Mechanical Engineers for their very great kindness.

BUOYS FOR CURRENT READINGS.

E. R. GRAY, '13

Under instructions from Mr. C. H. Rust, C.E., City Engineer for Toronto, a series of observations were conducted during the summer of 1909, dealing with current movements in Lake Ontario, near Toronto. At the outset it was found rather difficult to obtain a type of float which would give a satisfactory indication of the true direction, and rate of flow of the subsurface current without it being unduly affected by wind or surface motion.

In the first instance a metal float of the type and dimensions shown in Fig. 1 was used.

It consisted of a double cone-shaped, air-tight float, made of tin, to the top of which a short length (2 feet) of 1-4 gas piping was attached. This rod carried a small movable sheet-iron flag, by which the buoy was located when in use.

At the lower end of the float more piping was fastened, the length of which depended upon the depth of current to be gauged.

A sheet of galvanized iron 12 in. x 4 in. was then fixed rigidly to the lower end of this rod, to take the pressure of the current.

It will readily be seen that the large area which the body of this float offered to the wind and surface current, was out of all proportion to the small vein attached to the rod below, and that if, in turning, the vein offered its thin end to the direction of the current, there was practically no subsurface resistance plane.

This buoy was soon discarded, as no reliable results of the movement of subsurface currents could be obtained.

The buoy as shown in Fig. 2 was then tried with fairly satisfactory results, but proved so heavy and cumbersome that it soon gave way to a better type, viz., that shown in Fig. 3. The second style of buoy consisted of a small block of oak 4" x 4" x 6", to the centre of which a small swivel was stapled. Varying lengths of copper wire, No. 18, dependent upon the depth for which the buoy was to be used, were fastened to the swivel.

To the loose end of the wire a slight strip of wood, about two feet in length was attached, and to the other end of the strip a small piece of white cotton was tacked, in order to facilitate the location of the buoys on the water.

About the middle of this strip, two or three ordinary net corks were wired in order to carry the strip upright, when the oak block was weighted carefully to the proper depth.

On account of the weight of the oak block, which frequently

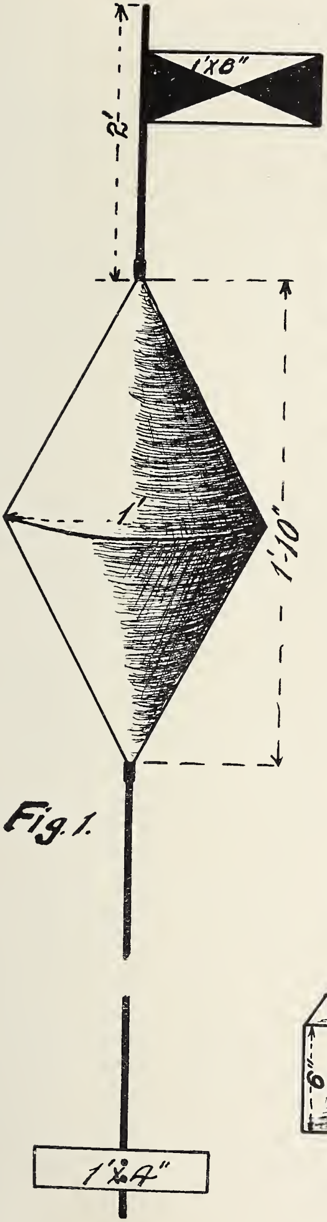


Fig. 1.

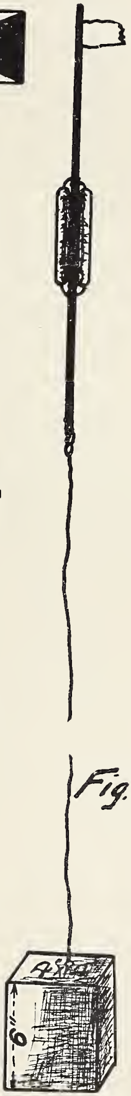


Fig. 2.

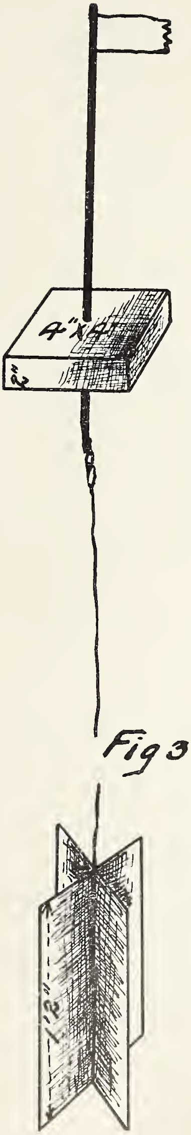


Fig 3

broke loose, this buoy was abandoned, and the type shown in Fig. 3 substituted with better results.

Two pieces of tin 10″ x 14″ were riveted together down the centre with three copper rivets. The opposite sides of both pieces of tin were then bent through ninety degrees, thus forming two vertical planes at right angles. A hole was punched at the centre of one end and through it a copper wire loop was bent. To the loop was fastened an end of the required length of copper wire, forming the submerged part of the buoy.

The float was made of a block of cedar 4″ x 4″ x 2″, painted to keep out the water. Experiments with other woods demonstrated the fact that cedar gave the best results for buoyancy and economy. In the centre of the block a small hole was bored, through which a strip of wood about 2 feet long was passed, allowing some six inches to project from one side.

To the long end a small piece of white cotton was tacked to act as a flag and to the lower end a small loop was wired.

To complete the buoy the loose end of the wire attached to the submerged vein is fastened through this loop.

It was found that the use of a loop in attaching the wire to the float was a good plan, otherwise the continual swinging and bending motion given to the float by the movement of the waves broke the rigid wire fastening, resulting in the loss of buoys and a negative observation.

With this buoy, then, it will readily be seen that extremely accurate results may be obtained regarding the movement of subsurface currents. The small cedar float and mast offer very little surface to surface currents and wind action, while of the large surface on the lower or submerged part of the buoy, half may at any time offer resistance to the current motion, no matter in what direction the vein may turn.

Larger sizes were tried, but in this instance the results were not shown to be proportional to the addition of metal used.

For observation, a number of buoys of varying lengths were placed in the water together, at a point the exact location of which was known.

They were then allowed to drift, and were located later and collected when deemed necessary. In this case the referencing was done by the use of the sextant. Two angles were read from the buoy upon three objects—one of which was common to both angles—of known position; for instance, certain prominent towers or chimneys. These angles were then plotted on a plan and the buoys located.

This may be done when the buoys do not pass beyond the range of the shore, with good results. It also proved helpful in conducting these observations, to note the speed and direction of the wind, in relation to the movement of the buoys. These comparisons gave very interesting results.

The observations were carried on under the direction of Mr. F. W. Thorold, B.A.Sc., Assistant City Engineer.

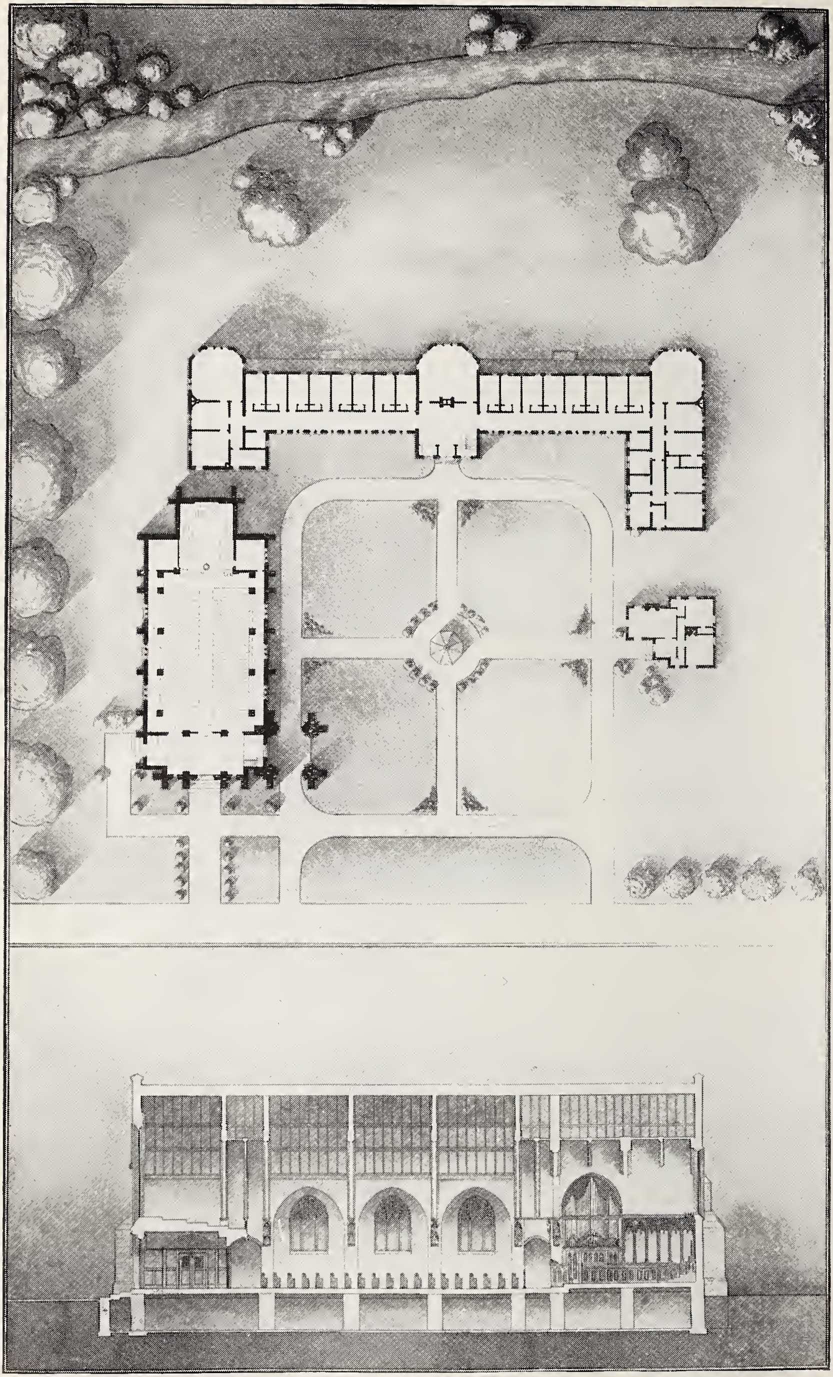
Record of Winds, 1908, Obtained From the Meterological Observatory.

	June.	July.	Aug	Dec.	Sept.	Oct.	Nov
N.	2	0	2	0	1	0	3
S.	12	1	0	0	0	0	0
E.	15	11	10	14	12	6	2
W.	1	19	16	13	19	24	19
Variable			2	2	3		1

1909.

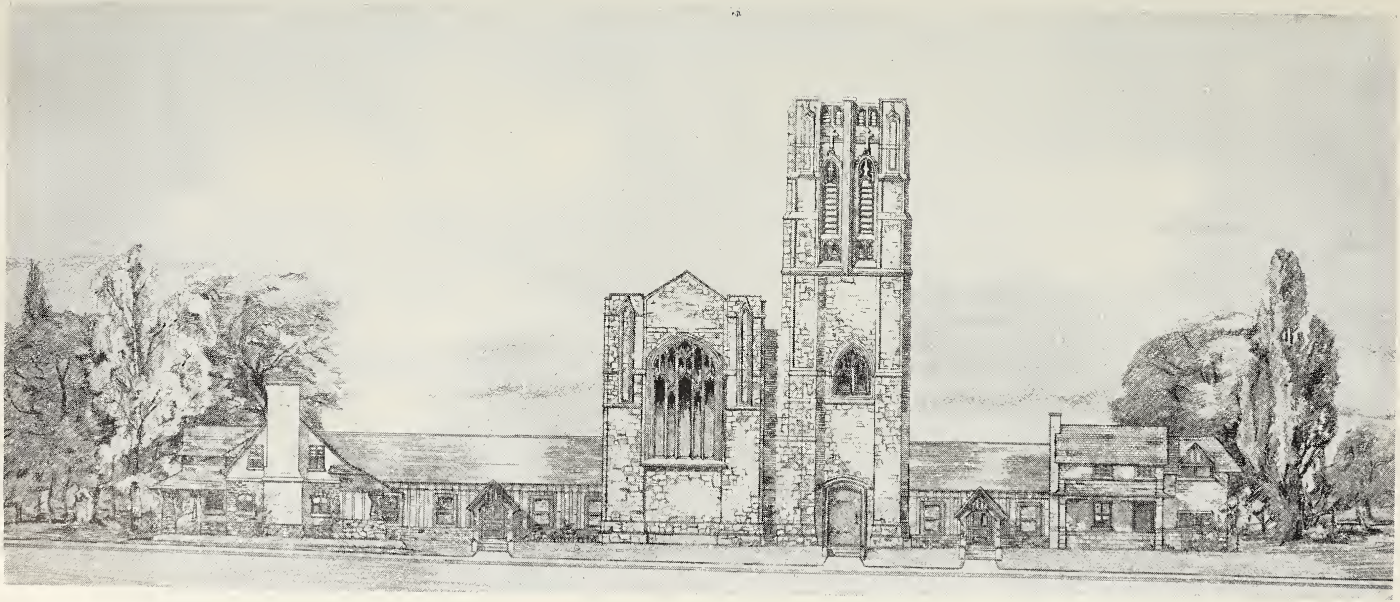
	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.
N.	7	3	11	4	1	0	1	1	1
S.	2	0	1	2	2	0	0	0	0
E.	4	5	6	11	12	10	10	12	11
W.	18	18	11	8	11	16	18	15	13
Variable		2	2	3	5	4	2	3	3

Of 485 days observed 50.5% were westerly.
" " " " 31.1% " easterly.
" " " " 7.6% " northerly.
" " " " 6.7% " variable.
" " " " 4.1% " southerly.

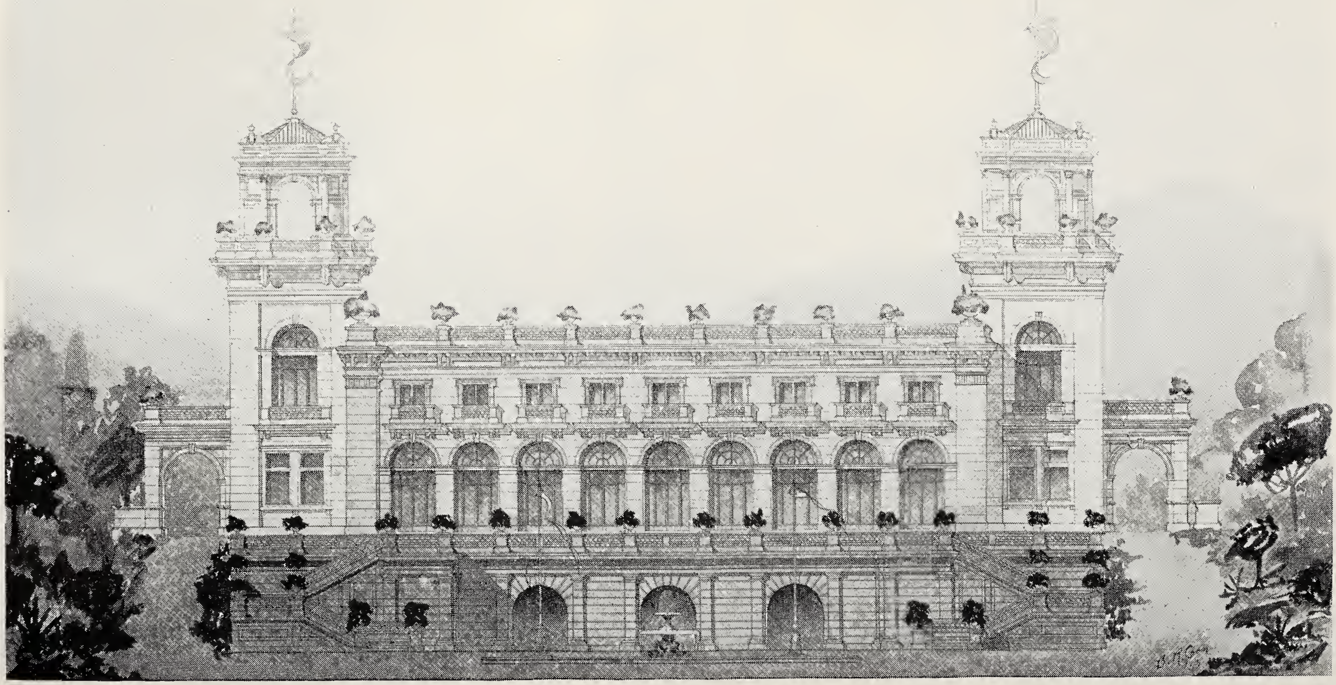


A HOME OF REST FOR AGED POOR, WITH DETACHED CHAPEL AND MANSE

Designed bv T. L. Rowe, '11

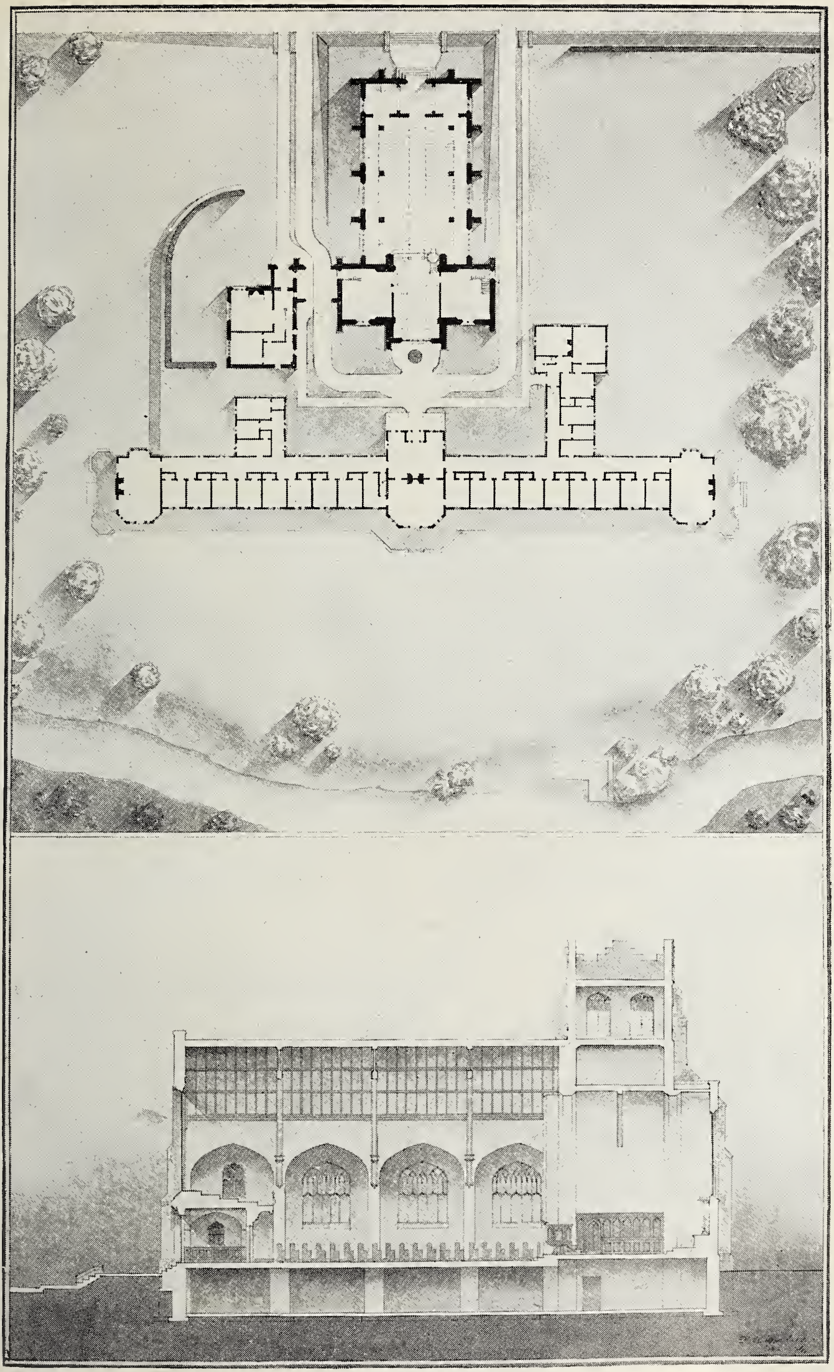


A HOME OF REST FOR THE AGED POOR, WITH DETACHED CHAPEL AND MANSE
Designed by Paul Sheard, '11



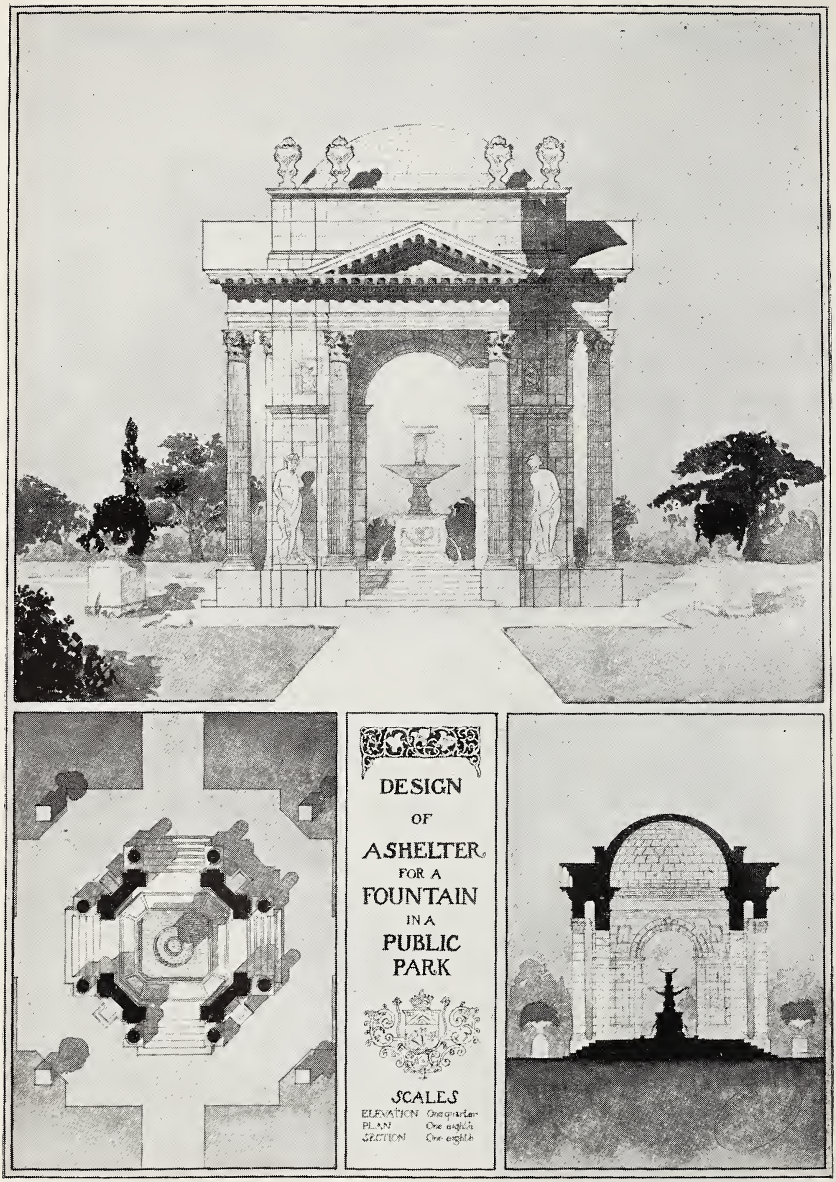
A RESTAURANT IN A PUBLIC PARK

Designed by B. R. Coon. (Second Year Student)

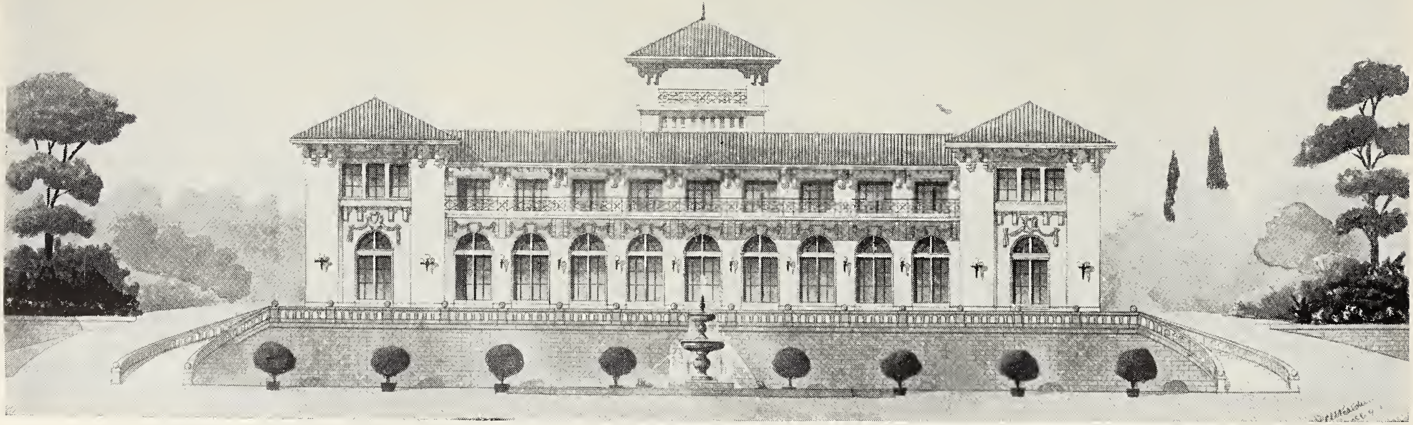


A HOME OF REST FOR AGED POOR, WITH DETACHED CHAPEL AND MANSE

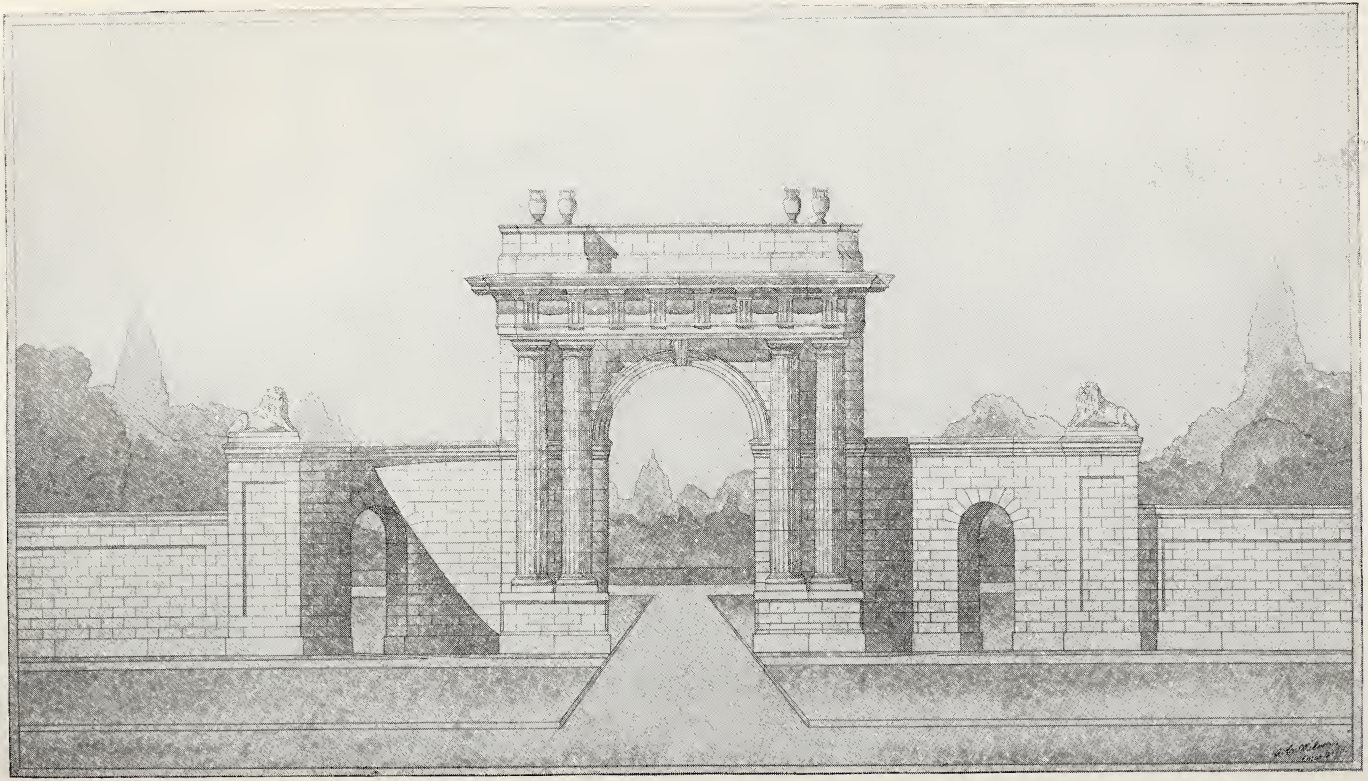
Designed by H. H. Madill, '11



A SHELTER FOR A FOUNTAIN IN A PUBLIC PARK
Designed by R. S. McConnell. (Second Year Student)



A RESTAURANT IN A PUBLIC PARK
Designed by L. C. M. Baldwin. (Second Year Student)



A GATEWAY TO A RICH MAN'S ESTATE
Designed by A. C. Wilson. (First Year Student)

PENNSYLVANIA ELECTRIFICATION.

H. A. COOCH, B. A. Sc.

The problem of transportation in the city of New York is one which has puzzled the minds of the most talented and experienced engineers since 1871.

New York, of course, is so situated that either bridging or tunneling was necessary for a terminal station in the heart of the city.

In 1884 a proposition was discussed to build the "North River Bridge," with a span almost twice that of the Brooklyn Bridge, but due to the enormous cost both in property and construction, as well as the possible obstruction to navigation, it was abandoned.

The tunnel proposition under the North and East rivers was often considered, but was out of the question as far as steam locomotives were concerned.

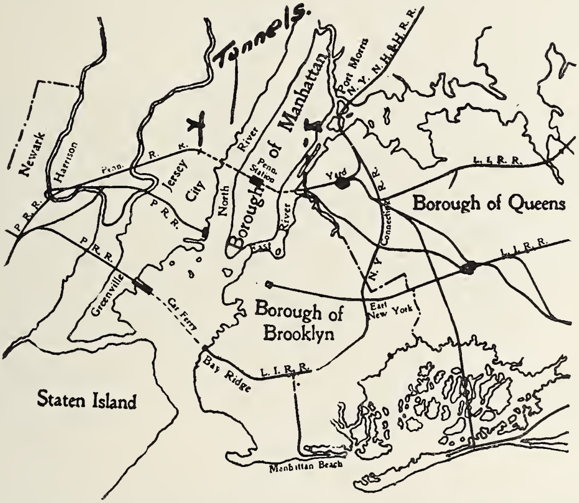


Fig. 1. Sketch of New York and Vicinity.

The successful development of the electric motor for traction purposes, first in quite small units, as applied to car axles, and during the past ten years in sizes so large, and capacity so great, as not only to equal, but in the case of the "Pennsylvania Locomotive," to exceed the power of any steam locomotive heretofore built, has solved the above problem.

The electrification is entirely of direct current, which, for a comparatively short mileage, compares very favorably with the single phase.

The length of track electrified is twenty miles, extending from Harrison, N. J., to Long Island City, about twelve miles being tunneled in all. This can be plainly seen by referring to Figure 1.

It has been estimated that the ratio between the coal burned for operating passenger trains by electric, and that for steam locomotives is 1 to 2, which seems to more than counterbalance the necessary initial outlay, while, as far as convenience and cleanliness of operation is concerned, electrical equipment is much more satisfactory.

Thus the Pennsylvania Railroad has fitted up one of the most elaborately and magnificently equipped terminal stations in the world. (Fig. 2.)

Altogether the operations around New York city have cost the railroad nearly $150,000,000.

The new station itself is located on 7th Avenue, between 33rd and 35th Streets, and is handy to all parts of the city.

At present the passenger traffic through the new station numbers about 500 trains per day, while the construction has been so made as to allow of a possible 1,000 per day. All the traffic, of course, with a few exceptions, which is handled by the new station, is passenger, the freight being taken across the river by car ferries from Greenville to Bay Ridge.

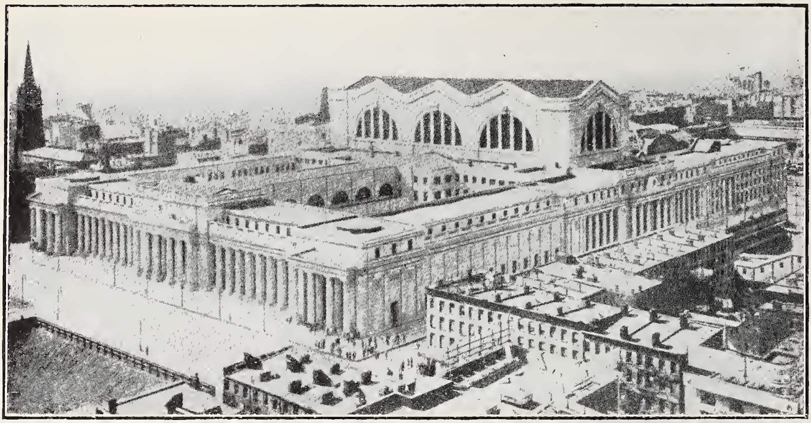


Fig. 2. Pennsylvania R. R. Terminal Station, New York City.

The locomotive itself (Fig. 3) is designed in two half units. The design of the articulation between them is such that the leading half serves as a leading truck, and the other half as a trailing truck for travel in either direction.

This type of locomotive has also a very peculiar method of drive, which distinguishes it from all others. Instead of the usual methods of drive, i.e., of gear wheels, as in ordinary street cars; quill drive, as in the case of the New York, New Haven and Hartford; or direct drive, as in the case of the New York Central type, connecting rods on the drivers are connected by cranks to the crank or eccentric on the motor, like ordinary steam locomotives. This arrangement can be quite clearly seen in Fig. 4.

The drivers are 72 in. in diameter, and the pony trucks 36 in. in diamteer. The total wheel base is 23 ft. 1 in. per half.

The weight of the locomotive completely equipped is 332,000 lbs., while the weight on the drivers is 207,800 lbs.

The motors (Fig. 5.), two of which are placed on each engine, are connected for series-parallel operation, but either motor can, without the aid of the other, run the engine should the occasion arise. Each unit is equipped with the Westinghouse electro-pneumatic system of multiple control, so that in a case of a particularly heavy load, as many locomotives as necessary can be used, each controlled by the master controller in the front cab of the leading engine.

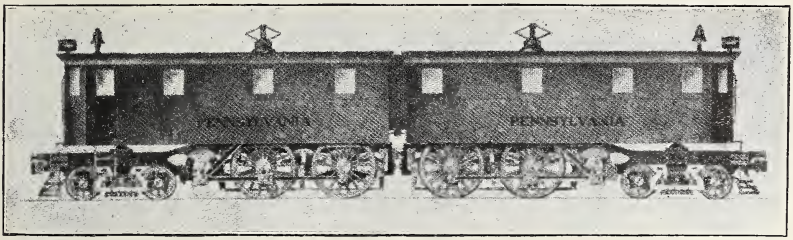


Fig. 3. Sketch of Pennsylvania Locomotive.

The location of the motors is high above the driving axles, which means that high speeds are possible on turning without any extreme stresses on the rails.

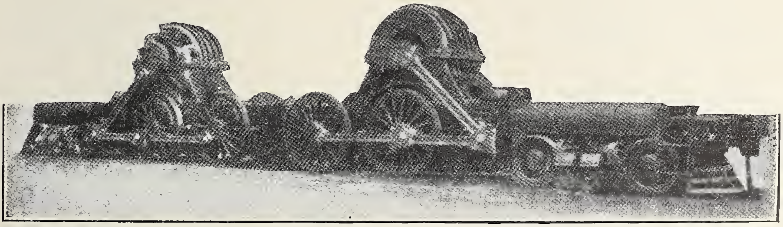


Fig. 4. General View of Running Gear.

With one motor alone the locomotive can exert a tractive effort of 30,000 pounds, the maximum possible tractive effort being 69,300 pounds, although 79,200 pounds have been developed.

The maximum capacity of the locomotive with the two motors is 4,000 h.p. for short periods, and 2,000 h.p. continuously.

The motors are designed to operate on 600 volts d.c., and each weighs 45,000 lbs.

The maximum speed obtainable is 95 miles per hour, and the maximum guaranteed speed is 80 miles per hour.

The motors themselves carry 2,900 amps., at 600 volts full load, and operate at an efficiency at this load of 92.1 per cent. They take their power from a protected third rail, and are also

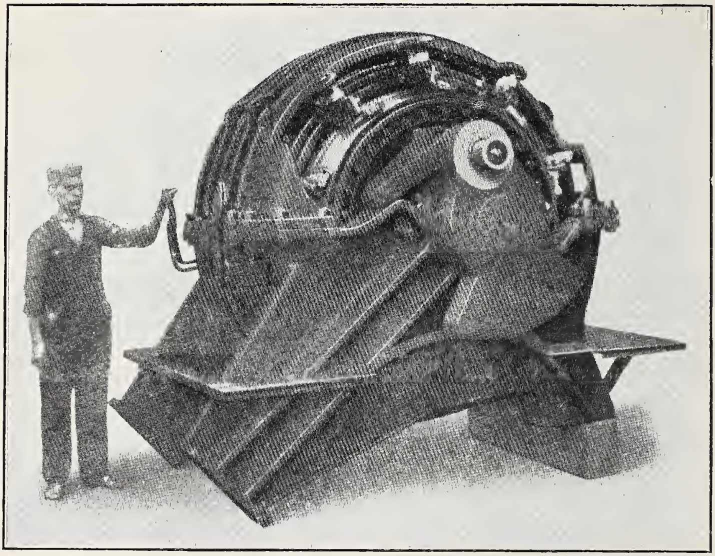


Fig. 5. Detail View of Motor.

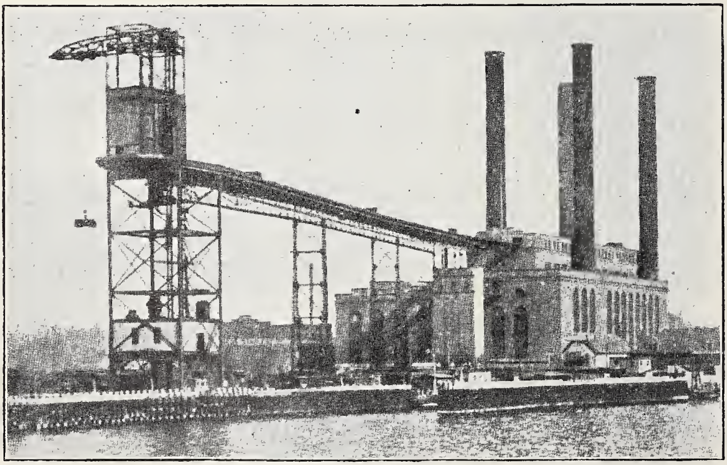


Fig. 6. Power Station, Pennsylvania Electrification.

connected to a pantagraph which, for safety purposes, is used together with an overhead construction in the case of railroad crossings too wide for the momentum of the train to carry them across at a reasonable speed.

The motors are provided with commutating poles, consequently have sparkless commutation, even when carrying the momentary heavy currents used in acceleration, which are far in excess of the normal running current of the motors.

Notwithstanding the good commutation resulting from the presence of auxiliary poles, provision is made to relieve the driving gear from the dangerous shocks that would result in the event of an accidental flash-over at the brushes. A flash-over practically stops the motor armature for an instant, and unless the shaft can slip in the armature core the effect on the driving gear would be disastrous.

This is prevented by a slip clutch between the armature core and its spider. The clutch can be set by means of the springs, so that slipping will start at any overload. In the case of most of the locomotives these clutches are set to slip at 100 p.c. overload, and consequently this renders the pins and connecting rods quite safe.

The power for operation of the trains is supplied from the power plant (Fig. 6), located at Long Island City. At present it has a capacity of 40,000 k.w. and is capable of an extension to 75,000 k.w.

The total number of locomotives used by the Pennsylvania is 24, the cost being about $50,000 apiece. These, together with 280 multiple unit cars, take care of all the present traffic.

OBITUARY.

Roy B. Ross.

The death, in far-away Buenos Ayres of Roy B. Ross, '05, a few months ago, lessened our number by one of the most promising young engineers of the Faculty of Applied Science has produced. He received his early education at Ingersoll, Ontario, and afterwards came to Toronto to reside, attending Toronto Junction High School. Mr. Ross entered upon his course in Engineering in 1900, and after completing two years became identified with the Otis Elevator Company of Yonkers, N.Y. In 1904 he resumed his course.

Roy B. Ross

After graduating with honors he became associated with Haney & Miller, in this city. Leaving their employ, he joined the International Marine Signal Co., in their Ottawa office. His engineering ability and ingenuity gained for him a position with the same firm in New York City a short time later. Then in 1909, Mr. Ross went for them to further their interests in Argentine Republic, where he remained until the spring of 1910. He spent the summer in his native city, Toronto, returning to Buenos Ayres, early last fall. It was in the south that his remarkable progress was checked and his early death, at the age of 26 years, occurred.

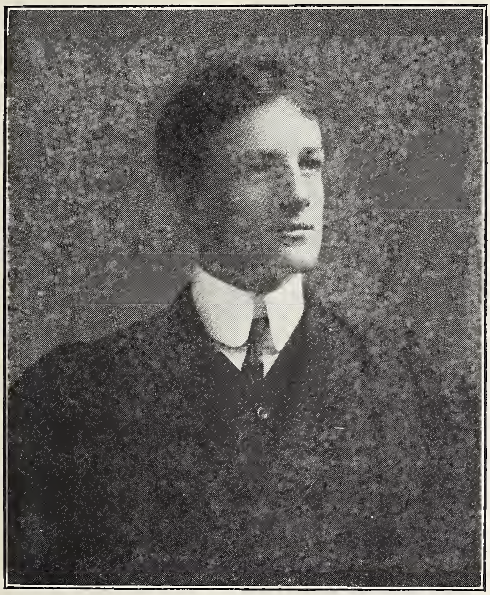
Mr. Ross was known and admired by every classmate for his congenial disposition and exemplary companionship, and his devotion to the ideals that characterize the successful engineer. In the crystallization of present into past, the personality of Roy B. Ross will long be remembered as a brilliant college man, and a man of promise. For those in Toronto, to whom the sad news of his death in strange and distant Argentine, came as a bolt from blue skies, we extend the sympathy of the class '05 and of the School.

H. Stanley Fierheller, B.A.Sc.

The Faculty of Applied Science lost one of the brightest of her younger members, and the School one of her most promising graduates in the early summer of 1910, when H. Stanley Fierheller passed away.

Stan. received his early training in Markham public schools and collegiate, and after obtaining the highest standing there became one of the most popular members of the class of '05.

Immediately after taking the degree of B.A.Sc., with honors, he joined the electrical department, taking charge of the lectures in electric circuits to the first year and the laboratory work of the fourth year. At the end of two years he obtained leave of absence and spent a year at research work, publishing at the end of the year an extended paper based upon his researches. He returned to the School in the fall of 1909, but ill-health forced him to resign.



H. Stanley Fierheller, B.A., Sc.

His work and his personality, as shown in the short time he was with us, will be a constant memorial to a real man.

Milton Thomas Culbert, B.A.Sc.

The death of Milton T. Culbert, on March 14th, removed from the engineering profession one of the cleverest men that the Canadian mining industry has ever known. Mr. Culbert was born in Granton, near London, Ontario, on May 29th, 1880. He received his public school training partly in Granton and finished in London, Ontario, where he passed his high school entrance in 1893, at the age of 13. He spent three years at the London Collegiate Institute, and left school to drift out to the foothills of the Rockies. The following summer he spent in Parry Sound, and while here visited the Calumet and Hecla, and the Bruce Mines, and took a deep interest in mining. Some of his mining friends persuaded him to take a mining course, to which his father readily consented. He passed his matriculation examination in 1898, and spent the next four years in the mining course of the School of Practical Science, graduating and taking his degree of B.A.Sc., both with honors.

Milton Thomas Culbert, B.A., Sc.

His first summer vacation was spent at Copper Cliff; the other three with Prof. Coleman on the geological survey of the Sudbury district. He also prepared the report on the Hutton Iron Range. In 1903-4 he was demonstrator in mineralogy and geology in the University of Toronto. In 1904 he compiled the map of the Sudbury Nickel Range. The following winter he went to the Western States for a short time, and spent some time in the refinery of the smelter at Trail, B.C. Hearing of the Cobalt find he came east again, and met Mr. M. J. O'Brien in the spring of 1905, and entering his service, proceeded to Cobalt, where he opened up and developed the O'Brien mine.

Mr. Culbert had always taken an active interest in the progress of the Faculty of Applied Science and Engineering. Since his taking up residence in the north country he has been at work on a collection of valuable ore specimens, which would have soon been complete, for presentation to the University. He was actively associated, also, in all that concerned the progress of the Cobalt and Temiskaming districts, being a member of the municipal council; a member of the council of the Cobalt branch of the Canadian Mining Institute; president of the Temiskaming Mine Managers' Association; and president of the Temiskaming S. P. S. Graduates' Club, as well as being prominent in Masonic and social circles.

His rapid advancement was checked by a fatal attack of appendicitis, and cut off death at the early age of 30 years.

The funeral in London was conducted under Masonic auspices, and was attended by a large delegation of mining and municipal men from the Cobalt district, showing the esteem and honor in which Mr. Culbert was held.

To Mrs. Culbert and her son, Milton, jr., and to Mr. Victor Culbert, B.A.Sc., '07, brother of the deceased, our heartfelt sympathy is extended.

PRESIDENT CAMPBELL'S RETIRING ADDRESS.

Gentlemen:—

This is the last time that I shall have the opportunity of addressing you as your president. I wish to thank each one of you for your hearty co-operation throughout my term of office.

The past year has seen the coming into effect of some important changes in the affairs of the Society, and with your permission I will review the work of the year.

The Society have had this year for the first time a secretary employed exclusively for its work. Mr. Irwin, who has occupied this position, has performed his duties as editor-in-chief of "Applied Science," and as manager of the supply department, in a manner highly satisfactory to the executive and to the members of the Society.

The supply department has had a record year. A permanent sales clerk has been employed there throughout the year. The new system of book-keeping has been used in this department as in the others. The policy here has been to extend the stock handled and to make only such profit as is necessary to meet the expenses of the Society. We would like again to draw the attention of the staff to the fact that should they desire to publish text books, covering any of the branches of our studies, the Society is now in the position financially to aid in the publication and distribution of such books.

Our monthly, "Applied Science," as you have heard from the editor's report, has had a good year. It continues to grow and promote more cordial relations between graduates and undergraduates, and we look forward to its being issued monthly throughout the year, rather than for but six months of the year, as at present. The monthly has done much to build up the feeling of "Boost for the School."

Our Annual Dinner was a success. At it we entertained officers and members of the Toronto Board of Trade, the chairman and some members of the Royal Commission on Technical Education, as well as representatives from the various educational institutions and technical societies and journals of the city.

A new social function was started this year by the Society. We held the first annual Science dance. The dance was a great success socially and financially, and the thanks of the Society are due to the committee in charge of it.

The papers read before the Society have been of interest and the meetings well attended. Speakers from Chicago, Montreal, and Ottawa, at the expense of considerable time and money, have come to Toronto to address us and to give us the benefit of their experiences. Good papers have been the rule, too, in the sectional meetings, and excursions arranged by the vice-presidents, assisted by the staff, have been attended with profit.

The most cordial relations have existed between the students and the staff, whom we have found always willing to aid in the advancement of the Society. Your thanks are especially due to Dean Galbraith, Prof. Wright, and to our representatives on the University Senate, Mr. E. A. James and Mr. C. H. Mitchell, for their aid in carrying out the work of the year.

One grievance we have, in the cramped condition of our reading room and library. Extension there would indeed be appreciated by our members. Some new engineering books have, however, been added to the central library and sub-libraries this year, and with the adoption of some system of indexed cataloging to make the books more available, we may have hopes for a solution of this trouble in the not too distant future.

I have had reason to congratulate myself on the very able executive with whom I have been associated in carrying on the affairs of our Society. To them belongs the credit for anything that has been accomplished this year. I commend to you for your approbation the members of that executive. I congratulate you on your choice for the coming year, and feel confident that under their guidance the Society's best interests will be advanced.

In conclusion, let me thank you for the honor you have done me, an honor which it has always been my honest endeavor to merit.

I take great pleasure in introducing to you your president-elect for 1910-11, Mr. A. W. McPherson.

THE TREASURER'S REPORT.

Toronto, April 1st, 1911.

Gentlemen—

I beg to submit my report as treasurer of the Engineering Society during the year 1910-11. The system of bookkeeping recommended by the auditor a year ago, and described in the revised edition of the Constitution, has been very satisfactory, enabling us at all times to have our financial affairs under easy supervision.

Through the medium of the Supply Department the Society ventured this year upon the publication of a number of booklets bearing upon courses of lectures. Among these were "Notes on Descriptive Geometry for the Third Year," by Mr. J. R. Cockburn; "Notes on Dynamics of Rotation," by Prof. W. J. Loudon; "Notes on the Chemistry of Fuels," by Dr. Ellis, and "Notes on the Calculus," by Mr. S. Beatty, the latter being a small textbook of some seventy pages. The department also began the sale of photographic supplies, and, in short, broadened out extensively to meet the needs of undergraduates.

Applied Science has, during the year, almost succeeded in refunding to the Society the $275 paid to the former editor last summer, this amount having been due him upon commission basis, and having been left over by the former executive. This has evidently been an exceedingly successful year for the monthly.

A summary of the business of the year appears herewith:

Cash Book Balance.

From April 1st, 1910, to April 1st, 1911.

RECEIPTS.

From 1909-10 Executive:	
Cash in Bank	$ 324.84
Cash in Till	28.50
Deficit of Cash	2.29
Merchandise Sales	7,563.68
Applied Science	1,377.72
Fees	748.00
Annual Dinner	509.65
Annual Dance	40.75
Telephones	49.75
Outstanding Cheques, March 31st, 1911	440.08
	$11,085.26

DISBURSEMENTS.

To 1911-12 Executive—	
Cash in Bank	$ 344.09

Forward	$ 344.09
Cash in Till	417.49
Applied Science	2,011.24
Supply Department—	
Merchandise	5,513.31
Salaries	966.33
Meetings and Entertainment	229.55
Annual Dinner	715.06
Sundry Expenses	700.44
Telephones	187.75
	$11,085.26

Balance Sheet.

RESOURCES.

Merchandise, as per inventory Mar. 31, 1911	$1,676.05
Cash on Hand	417.94
Cash in Bank	344.09
Accounts Due Supply Department	70.66
Accounts Due Applied Science	1,078.98
Fees Outstanding	70.00
Dinner Deposits	40.00
Office Equipment less 10 p.c. depreciation	212.85
	$3,910.57

LIABILITIES.

Accounts Outstanding Applied Science	2.52
Accounts Outstanding Supply Department	91.11
	93.63
Surplus	3,816.94
	$3,910.57

Surplus March 31st, 1911	$3,816.94
Surplus March 31st, 1910	2,862.48
Net Gain for Year	$ 954.46

Respectfully submitted,

M. B. WATSON,

Treasurer.

APPLIED SCIENCE

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Vol. IV - New Series

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ENGINEERING BUILDING
UNIVERSITY OF TORONTO, CANADA

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LIST
OF
GRADUATES
AND THEIR
BUSINESS ADDRESSES

◆

APPLIED SCIENCE
APRIL, 1911

GRADUATES.

Graduates are requested to inform the Secretary of changes in their addresses.

1881.

1. J. L. Morris, C.E., O.L.S. — Pembroke, Ont.
   Morris and Moore Land Surveyors and Architects.

1882.

1. D. Jeffrey — Windsor, Missouri.
   Contractor.
1. J. H. Kennedy, C.E., O.L.S., — Vancouver, B.C.
   Chief Engineer, Great Northern Ry.
1. J McAree, B.A.Sc., D.T.S. (Deceased.)

1883.

1. D. Burns, O.L.S., A.M., Can. Soc. C.E., — Pittsburgh, Pa.
   Instructor in Mathematics and Plan Drawing, Carnegie Technical Schools.
1. G. H. Duggan, M. Can. Soc. C.E., — Glace Bay, N.S.
   Dominion Coal Co., Ltd.
1. J. W. Tyrrell, C. E., D.L.S., — Hamilton, Ont.
   Tyrrell & MacKay, Consulting Engineers and Surveyors.

1884.

1. W. C. Kirkland, — New Orleans, La.
   Principal Assistant Engineer, Drainage, Sewage and Water Board of New Orleans.
1. J. McDougall, B.A. (Deceased.)
1. A. R. Raymer, — Pittsburgh, Pa.
   Assistant Chief Engineer, P. & L. E. Ry.
1. James Robertson, O.L.S., — Toronto, Ont.
   Commissioner, The Canada Co.
1. E. W. Stern, M. Am. Soc. C.E., — 103 Park Ave., New York.
   Consulting Civil Engineer.

1885.

1. J. F. Bleakley, — Bowmanville, Ont.
   Civil Engineer.
1. H. J. Bowman, D. & O.L.S., M. Can. Soc. C.E., — Berlin, Ont.
   Bowman & Connor.
1. E. E. Henderson, O.L.S., — Henderson, P.O., Me
   Civil Engineer.
1. B. A. Ludgate, O.L.S., — Pittsburgh, Pa.
   Assistant Engineer, P. & L. E. Ry.
1. O. McKay, O.L.S., — Walkerville, Ont.
   Civil Engineer and Surveyor.

1886.

1. A. M. Bowman, D.L.S., Pittsburgh, Pa.
Pennsylvania Contracting Co.
1. E. B. Hermon, D. & O.L.S., Vancouver, B.C.
Assistant Engineer Vancouver Power Co.
1. Robert Laird, O.L.S., Haileybury, Ont.
Laird & Routly, Engineers and Surveyors.
1. T. Kennard Thomson, C.E., M. Can. Soc. C.E., M. Am. Soc. C.E., Hudson Terminal Building, New York.
Consulting Engineer.
1. H. G. Tyrrell, C.E., A.M. Can. Soc. C.E., 2151 Fulton Ave., Cin., Ohio.
Chief Engineer, The Brackett Bridge Co.

1887.

1. J. C. Burns (deceased.)
1. A. E. Lott, Los Angeles, Cal.
Consulting Railway Engineer, 441 Bradbury Building.
1. A. L. McCullough, O.L.S., B.C.L.S., A.M. Can. Soc. C.E., Nelson, B.C.
Engineer and Surveyor.
1. F. Martin, M.B., O.LS.,
Physician.
1. C. H. Pinhey, D. & O.L.S., 110 Wellington St., Ottawa, Ont.
1. J. Rogers, O.L.S., Mitchell, Ont.
Town Engineer.

1888.

1. J. F. Apsey, O.L.S., 3205 Wallbrook Ave., Baltimore, Md.
Assistant Divison Engineer, Baltimore Sewerage Commission.
1. W. T. Ashbridge, C.E., 1444 Queen St. E., Toronto, Ont.
Engineer and Surveyor.
1. Edward F. Ball, A.M. Can. Soc. C.E. , 335 Madison Ave., New York, N.Y.
Chief Assistant Engineer, Land and Tax Department, N. Y. Central & Hudson River Railroad.
1. D. B. Brown, O.L.S., Quebec, P.Q.
Locating Engineer, Transcontinental Ry. (G.T.P.)
1. C. M. Canniff, Toronto, Ont.
Fielding & Canniff Co., Consulting Engineers.
1. H. J. Chewett, B.A.Sc., C.E., A.M. Can. Soc. C.E., Manning Arcade, Toronto, Ont.
Mechanical Engineer, Evans Rotary Engine Co., Ltd.
1. J. Gibbons, D. & O.L.S., Ottawa, Ont.
Surveying Staff, Department of Interior.
1. R. McDowall, O.L.S., C.E.,, A.M. Can. Soc. C.E.,
Town Engineer. Owen Sound, Ont.
1. G. W. McFarlen, O.L.S., Toronto, Ont.
City Engineer's Staff.
1. C. J. Marani, Anacortes, Wash.
Designing and Consulting Structural Engineer for the Russia Cement Co
1. G. R. Mickle, B.A., Toronto, Ont.
Mine Assessor, Province of Ontario.

1888—*Continued.*

I. J. H. MOORE, O.L.S., Smith's Falls, Ont.
Town Engineer.

I. G. H. RICHARDSON, Edmonton, Alta.
Managing Director Yellowhead Pass Coal & Coke Co.

I. K. ROSE, Curry Bldg., Toronto.
Manager, Evans Rotary Engine Co. of Canada.

I. J. E. ROSS, D. & O.L.S, Kamloops, B.C.
Surveying Staff, Department of Interior.

I. C. H. C. WRIGHT, B.A.Sc., Toronto, Ont.
Professor of Architecture, University of Toronto.

1889.

I. B. CAREY, Toronto, Ont.

I. W. J. CHALMERS, Pittsburgh, Pa.
With Vanport Beaver Co.

I. W. A. CLEMENT, M. Can. Soc. C.E., Vancouver, B.C.
City Engineer.

I. G. F. HANNING, Toronto, Ont.

I. H. E. T. HAULTAIN, C.E., M. Can. Soc. C.E., Toronto, Ont.
Professor of Mining Engineering, University of Toronto.

I. J. IRVINE, Vancouver, B.C.
Locating Engineer, C.N.R.

I. D. D. JAMES, B.A., B.A.Sc., 227 George St., Toronto.
Surveyor.

I. F. X. MILL, (deceased.)

I. H. K. MOBERLEY, D. & S.L.S., Moosomin, Sask.
District Engineer and Surveyor.

I. T. R. ROSEBRUGH, M.A. Toronto, Ont.
Professor of Electrical Engineering, University of Toronto.

I. T. WICKETT, M.D., 362 Cannon St. E., Hamilton, Ont.
Physician.

1890.

5 W. E. BOUSTEAD, (deceased).

I. F. M. BOWMAN, O.L.S., C.E., Pittsburgh, Pa.
Secretary & Structural Engineer, Riter-Conley Mfg. Co

I. M. A. BUCKE, M.E. (deceased).

I. G. D. CORRIGAN, (deceased).

I. J. A. DUFF, B.A., (deceased).

I. A. B. ENGLISH, (deceased).

I. N. L. GARLAND 76 Wellington St. W., Toronto, Ont.

I. J. HUTCHEON, O.L.S., Guelph, Ont.
Engineer and Surveyor.

I. W. L. INNES, O.L.S., C.E., Simcoe, Ont.
Manager, Dominion Canners, Ltd.

I. E. B. MERRILL, B.A., B.A.Sc., M. Can. Soc. C.E., M. Am. Inst. E.E.
Toronto, Ont.
Consulting Engineer, Toronto General Trusts Building.

1890—*Continued.*

1. J. R. Pedder (deceased).

3. R. A. Ross, E.E. 80 St. Francois Xavier.St., Montreal, Que
Ross & Holgate, Consulting Electrical and Mechanical Engineers.

1. T. H. Wiggins, O.L.S., Saskatoon, Sask.
Civil Engineer and Dom. Land Surveyor.

1. W. J. Withrow, Ottawa, Ont.
Patent Examiner, Patent Office.

1891.

1. H. J. Beatty, O.L.S., Eganville, Ont.
Engineer and Surveyor.

1. T. R. Deacon, O.L.S., M. Can. Soc. C.E., Winnipeg, Man.
President and General Manager, Manitoba Bridge & Iron Works,Ltd.

1. C. W. Dill, M. Can. Soc. C.E., Toronto, Ont.
C. *W. Dill & Co., Civil Engineers and Contractors, 318 Continental Life Building.*

5. O. S. James, B.A.Sc., 227 George St., Toronto, Ont.

1. A. Lane (deceased).

1. J. E. McAllister, B.A.Sc., C.E., Greenwood. B,C.
Manager, British Columbia Copper Co., Ltd.

3. E. B. Merrill, B.A., B.A.Sc., M. Can. Soc. C.E., M. Am. Inst. E.E. Toronto, Ont.
Consulting Engineer, Toronto General Trusts Building.

1. J. E. A. Moore, C.E., 10074 Kee Mar Court, Cleveland, O.
Consulting and Contracting Engineer.

1. W. Newman, O.L.S., A.M. Can. Soc. C.E., Windsor, Ont.
Consulting Engineer.

1. J.K. Robinson (deceased).

1. W. B. Russel, 318 Continental Life Bldg., Toronto, Ont.
Civil Engineer and Contractor.

1. G. E. Silvester, O.L.S., M. Am. Inst. M.E., Copper Cliff, Ont.
Chief Engineer, Canadian Copper Co.

1. H. D. Symmes, Niagara Falls S., Ont.
Engineer and Contractor.

1892.

1. J. R. Allan, O.L.S., Macleod, Alta.
Ranchman.

1. T. H. Alison, B.A.Sc., C.E., Bayonne, N.J.
Secretary and Chief Engineer, Bergen Point Iron Works.

1. A. G. Anderson, Port Dover, Ont.
Hardware Merchant.

1. C. Fairchild, D. & O.L.S., Brantford, Ont.
Surveying Staff, Department of Interior.

1. J. B. Goodwin, B.A.Sc., Gasport, N.Y.
Superintendent of Construction, Empire Eng. Corporation of New York.

4. C. E. Langley, Continental Life Bldg., Toronto, Ont
Langley & Howland, Architects.

1892—*Continued.*

1. A. T. LAING, B.A.Sc., Toronto, Ont.
Secretary, Faculty of Applied Science, University of Toronto.

1. E. J. LASCHINGER, B.A.Sc., M.E., Johannesburg, Transvaal, S.A.
Mechanical Engineer, H. Eckstein & Co.

5. W. L. LAWSON, B.A.Sc, Stirling, Col.
Manager, Stirling Brush & Fort Morgan Co.

3. W. A. LEE, B.A.Sc. (deceased).

1. B. McENTEE, B.A.Sc., 28 Queen St. E., Toronto.
Stationer.

3. C. G. MILNE, B.A.Sc. (deceased).

1. CHAS. H. MITCHELL, B.A.Sc., C.E., M. Can. Soc. C.E., M. Am. Soc. C.E.
Consulting Hydro-Electric Engineer, Trader's Bank Bldg., Toronto.

1. N. L. PLAYFAIR, Midland, Ont.
Superintendent Playfair Lumber Co.

1. J. M. PRENTICE (deceased).

1. J. A. ROSS, Cleveland, Ohio.
Designer L. S. & M. S. Railway, Engineering Office.

1. ALBERT N. SMITH, Youngstown, Ohio.
Engineer, Wm. B. Pollock Co.

1. R. W. THOMSON, B.A.Sc., M.E., 4 Charles St., Toronto, Ont.
Mining Engineer.

3. A. V. WHITE, M.E., Toronto, Ont.
Mechanical Engineer.

1893.

1. A. G. ARDAGH, Barrie, Ont.
Land Surveyor and Civil Engineer.

.*H. F. BALLANTYNE, B.A.Sc. 244 Fifth Ave., New York, N.Y.
Architect.

1. G. L. BROWN, O.L.S., A.M. Can. Soc. C.E., Morrisburg, Ont.
Civil Engineer and Land Surveyor.

1.*L. C. CHARLESWORTH, D.L.S., Edmonton, Alta.
Director of Surveys for Alberta.

1. T. H. DUNN, O.L.S. Winchester, Ont.
Engineer and Surveyor.

1. J. M. R. FAIRBAIRN, P.L.S., Westmount, Que.
Assistant Engineer, C.P.R.

4.*W. FINGLAND, 334 Portage Ave., Winnipeg, Man.
Architect and Structural Engineer.

1. C. FORRESTER Toronto, Ont.

1.*WALTER J. FRANCIS, C.E., M. Can. Soc. C.E., M. Am. Soc. C.E.
Montreal, Que.
Consulting Engineer, 28 Commercial Union Building.

3.*A. R. GOLDIE, Galt, Ont.
Manager, Goldie & McCulloch Co.

3. S. C. HANLY, Midland, Ont.
Midland Engine Works Co.

4.*J. KEELE, B.A.Sc., Ottawa, Ont.
Geological Survey of Canada.

---

*Diploma with honours.

1893—*Continued.*

1. J. T. LAIDLAW, B.A.Sc., M.E., Cranbrook, B.C.
Consulting Mining Engineer.

3. F. L. LASH, Bandoeng, Java.
Manager, Electrical Supply Co., Board of Trade Building.

1. A. L. MCALLISTER, B.A.Sc., 612 Continental Life Bldg., Toronto, Ont.
Consulting Engineer.

1. T. J. MCFARLEN, 80 Waverley Rd., Toronto, Ont.
Chemist.

1.*A. J. MCPHERSON, B.A.Sc., D.L.S., Regina, Sask.
Superintendent of Highways, Province of Saskatchewan.

1. A. F. MACALLUM, B.A.Sc., C.E., Hamilton, Ont.
City Engineer.

1. W. T. MAIN, Wells St. Depot, Chicago, Ill.
Division Engineer, C. &. N. W. Ry.

1. V. G. MARANI, Cleveland, Ohio.
City Building Inspector, City Hall.

1. W. MINES, B.A.Sc., Cleveland, Ohio.
With Brown Hoisting Co.

3.*J. M. ROBERTSON, Montreal, P.Q.
Superintendent Repair and Testing Department, Montreal Light, Heat and Power Co.

1. R. RUSSELL, Pembroke, Ont.
Railway Contractor.

1.*F. N. SPELLER, B.A. Sc., Pittsburgh, Pa.
Metallurgical Engineer, National Tube Co.

1. R. H. SQUIRE, B.A. Sc., O.L.S (deceased).

1. W. V. TAYLOR, O.L.S., A.M.Can. Soc. C.E., Quebec, P.Q.
Quebec Harbour Commissioners.

1.*R. B. WATSON, Regina, Sask.
Department of Public Works.

1894.

3.*R. W. ANGUS, B.A.Sc., Toronto, Ont.
Professor of Mechanical Engineering, University of Toronto.

1. H. F. BARKER, Box 31, Halifax, N.S.

1. A. T. BEAUREGARD, B.A.Sc., East Orange, N.J.
Laboratory Engineer, Public Service Corporation of New Jersey.

1. A. E. BERGEY, Pittsburgh, Pa.
Carnegie Technical School.

3. D. G. BOYD, Toronto, Ont.
Draftsman, Public Works Department.

3. W. A. BUCKE, Toronto, Ont.
District Manager, Canadian General Electric Co.

1. J. CHALMERS, O.L.S., A. M. Can. Soc. C.E., Edmonton, Alta.
Structural Engineer, Department of Public Works.

4.*J. A. EWART, B.A.Sc., 193 Sparks St., Ottawa, Ont.
Architect and Engineer.

---

*Diploma with honours.

1894—*Continued.*

3. W. J. Herald, B.A.Sc., Toronto, Ont.
Engineering Department, Canada Foundry Co.

[illegible]. H. E. Job, B.A.Sc., Hamilton, Ont.
Manufacturer of Electrical Machinery and Apparatus.

3. A. C. Johnston, B.A.Sc., M.E., Philadelphia, Pa.
Vice-President and Chief Engineer, The J. M. Dodge Company.

1. S. M. Johnston, B.A.Sc., P.L.S., Greenwood, B C.
City Engineer.

1. J. E. Jones, Engineers' Club, New York, N.Y.

3. N. M. Lash, Montreal, P.Q.
Assistant Electrical Engineer, Bell Telephone Co.

1.*A. L. McTaggart, B.A.Sc., Rockefeller Bldg., Cleveland O
Office of A. G. McKee, Consulting Engineer.

3.*W. Minty, B.A.Sc., Blackburn Eng.
With Messrs. Yates & Thom, Ltd., Engineers.

3. C. J. Nicholson, Hamilton, Ont.
Assistant Engineer, Hamilton, Guelph & Waterloo Ry.

1. H. Rolph, Montreal, Que.
Secretary, John S. Metcalf Co., Ltd.

1. J. D. Shields, B.A.Sc., Toronto, Ont.
Sewer Engineer, Staff of City Engineer.

1. Angus Smith, O.LS., A.M. Can. Soc. C.E., Regina, Sask.
City Engineer.

3. A. K. Spotton, Galt, Ont.
Chief Engineer, Goldie & McCulloch Engine Works.

3. R. T. Wright, B.A.Sc., East Pittsburgh, Pa
Engineering Department, Westinghouse Machine Co.

1895.

1. J. Armstrong, B.A.Sc., Quebec, Que.
District Engineer, G.T.P. Ry.

3. A. E. Blackwood, 30 Church St., New York.
Manager New York Office, Sullivan Machinery Co.

1. E. J. Boswell, D.L.S., Winnipeg, Man.

3. G. Brebner (deceased).

3. W. M. Brodie, B.A.Sc., Pittsburgh, Pa.
With the Green Engineering Co. of Chicago.

3. L. L. Brown, 115 Broadway, New York.
Superintendent, The Foundation Co.

4. R. J. Campbell, Chicago. Ill.
Artist, Chicago Tribune.

3. A. W. Connor, B.A., C.E., 36 Toronto St., Toronto, Ont.
Bowman & Connor, Consulting Engineers.

1. J. S. Dobie, B.A.Sc., O. & D.L.S., Thessalon, Ont.

1. F. W. Guernsey, Bankhead, Alta
Assistant General Manager, Bankhead Mines, Ltd.

---

*Diploma with honours.

1895.—*Continued.*

4.*A. H. Harkness, B.A.Sc., Toronto, Ont.
Structural Engineer, Confederation Life Building.

3. H. S. Hull, B.A.Sc., Johnstown, Pa.
Structural Drawing, Cambria Steel Co.

3.*J. McGowan, B.A., B.A.Sc., Toronto, Ont.
Associate Professor of Applied Mechanics, University of Toronto.

3. W. N. McKay, Georgetown, Ont.
Manager, Bank of Hamilton.

3. H. L. McKinnon, B.A.Sc., Cleveland, Ohio.
Vice-President of The C. O. Bartlett & Snow Co.

1. W. W. Meadows, D. & O.L.S., Maple Creek, Sask.
Department of Public Works.

1. F. J. Robinson, D. & O.L.S., Regina, Sask.
Deputy Minister of Public Works. Saskatchewan.

3. F. T. Stocking, Toronto, Ont.
Hydro-Electric Commission.

3. R. C. C. Tremaine, B.A.Sc. (Deceased).

1896.

2.*J. W. Bain, B.A.Sc., Toronto, Ont.
Associate Professor of Applied Chemistry, University of Toronto.

2. L. T. Burwash, Dawson, Y.T.
Mining Recorder.

3.*G. M. Campbell, Riverside, Ill.
Superintendent, Power Apparatus Shops, Western Electric Co.

2. J. A. Decew, B.A.Sc., 615 Canadian Express Bldg., Montreal, Que.
Consulting Chemical Engineer.

3.*H. P. Elliott, B.A.Sc., E.E., Pittsburgh, Pa.
Electrical Engineer, Westinghouse Electric and Manufacturing Co.

3. W. C. Gurney, Toronto, Ont.
Vice-President, Gurney Foundry Co., Ltd.

3.*H. V. Haight, B.A.Sc., Sherbrooke, P.Q.
Chief Engineer, Canadian Rand Drill Co.

1. W. F. Laing, (deceased).

3. R.R. Lawrie, (deceased).

3. C. MacBeth, B.A Sc., (deceased).

3. J. A. MacMurchy, Pittsburgh, Pa.
Chief Draftsman, Turbine Department, Westinghouse Machine Co.

1. T. Martin, B.A.Sc., Calgary, Alta.
Assistant Divisional Engineer, C.P.R., Western Division.

3. R.R. Scheibe, Toronto, Ont.
Sales Manager, Brigdens Ltd.

1897.

2. E. Andrews, B.Sc., A.M.I., C.E., Portmadoc, N. Wales.
Resident Engineer, Maenofferen Slate Quarry Co., Limited.

2.*J. A. Bow, Great Falls, Mont.
B. & M. Smelter.

---

*Diploma with honours.

1897—*Continued.*

1. H. S. CARPENTER, B.A.Sc., O.L.S., Regina, Sask.
Superintendent of Highways, Department of Public Works.

5. H. W. CHARLTON, B.A.Sc., Ottawa, Ont.
Assistant Chemist at Experimental Farm.

4.*E. A. FORWARD, A.M. Can. Soc. C.E., Lockport, Man.
Engineer-in-charge, St. Andrew's Lock and Dam.

3.*A. T. GRAY, B.A.Sc., Schenectady, N.Y.
Designing Engineer on Steam Turbines, General Electric Co.

3. W. A. B. HICKS, Buffalo, N.Y.
With Lackawanna Steel Co.

4. C. F. KING, Toronto, Ont.
Rep. of Mortimer Co. of Ottawa.

1. H. W. PROUDFOOT, (deceased).

2.*A. H. A. ROBINSON, B.A.Sc., M.A.I., M.E., Haileybury, Ont.
Mine Inspector.

4. W. F. SCOTT, Toronto, Ont.
Structural Engineer and Consulting Architect.

3.*W. R. SMILEY, B.A.Sc., Cleveland, Ohio.
With Wellman-Seaver-Morgan Engineering Co.

2.*W.W. STULL, B.A.Sc., O.L.S., Sudbury, Ont.
Surveyor and Mining Engineer.

1.*M. B. WEEKES, B.A.Sc., D.L.S., Regina, Sask.
Department of Public Works.

1. E. A. WELDON, Winnipeg, Man.
Provincial Land Surveyor's Office.

1898.

1. W. H. BOYD, B.A.Sc., Ottawa, Ont.
Geological Survey of Canada.

2. W. E. H. CARTER, B.A.Sc., Toronto, Ont.
Consulting Mining Engineer, 83 &85 Front Street, East.

3. E. H. DARLING, A.M. Can. Soc. C.E., Hamilton, Ont.
Assistant Engineer, Hamilton Bridge Works Co.

1. W. F. GRANT, B.A.Sc., Sault Ste. Marie, Ont.
City Engineer.

1. J. S. KORMANN, B.A.Sc., Toronto, Ont.
Manager, Kormann Brewing, Ltd.

3. J. E. LAVROCK, Vancouver, B.C.
Draftsman, Hermon & Burwell.

4. D. MACKINTOSH, B.A.Sc., B. Arch., New York, N.Y.
Chief Superintendent F. M. Andrews, & Co., Metropolitan Tower.

1. F W. MCNAUGHTON, O.L.S., Winnipeg, Man.
Deputy Minister of Public Works.

1. J. H. SHAW, O.L.S., North Bay, Ont.
Surveyor and Engineer.

3. A. E. SHIPLEY, B.A.Sc., Nelson, B.C.
Manager, Nelson Coke & Gas Co.

---

*Diploma with honours.

1898—*Continued.*

3.*F. C. Smallpiece, B.A.Sc., Montreal, Que.
Assistant Manager, Canadian General Electric Co.

1. R. W. Smith, P.L.S., Revelstoke, B.C.
Surveyor.

1.*J. A. Stewart, M.A., Hamilton, Ont.
Engineer and Contractor, 67 Federal Life Building.

1.*H. L. Vercoe, Montreal, Que.
Chief Draftsman, Grand Trunk Pacific Ry.

3. T. A. Wilkinson, New York, N.Y.
Statistician, Westinghouse Church Kerr Co.

3. D.A. Williamson, B.A.Sc., Hamilton, Ont.
With Hamilton Bridge Works Co.

1899.

3.*T. Barber, Meaford, Ont.
Hydraulic Engineer, Chas. Barber & Sons.

2. J. T. M. Burnside, B.A.Sc. Montreal, Que.

3. L. B. Chubbuck, B.A.Sc., E.E., Hamilton, Ont.
Engineer, Canadian Westinghouse Co.

2. G. A. Clothier, Rossland, B.C.
Engineer, Le Roy Mining Co.

1. C. Cooper, Keokuk, Iowa.
Koekuk & Hamilton Water Power Co.

2. R. W. Coulthard, B·A.Sc., Blairmore, Alta.
General Manager, West Canadian Collieries, Ltd.

3. J. A. Craig, B.A.Sc., Toronto, Ont.
Office of Willis Chipman, C.E.

2. J. C. Elliott, Kelso, Ont.

3. W. E. Foreman, B.A.Sc., Pittsburgh, Pa.
Construction Dept., Westinghouse Electric and Mfg. Co.

3. E. Guy, B.A.Sc., Industry, Pa.
Engineering Dept., Westinghouse Electric and Mfg. Co.

3.*W. Almon Hare, B.A.Sc., A.M. Can. Soc. C.E., Toronto, Ont.
Secy-Treas. and Chief Engineer, The Standard Engineering Co.

1. R. Latham, B.A.Sc., Hamilton, Ont.
Chief Engineer, T. H. & B. Ry.

3. W. Monds, B.A.Sc., 36 Toronto St., Toronto, Ont.
Clark & Monds, Consulting Engineers.

1. J. Patterson, B.A., Toronto, Ont.
Physicist, Dominion Observatory.

3. A. S. H. Pope, B.A.Sc., Portland Oregon.
Pope & Wilcox, Electrical & Mechanical Engineers.

2.*G. E. Revell, B.A.Sc., Nelson, B.C.

3.*E. Richards, B.A.Sc., Toronto, Ont.
Assistant Electrical Engineer, City of Toronto.

3. G. A. Saunders, Wilkinsburg, Pa.
With Westinghouse Electric & Manufacturing Co.

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*Diploma with honours.

1899—*Continued.*

1.*T. SHANKS, B.A.Sc., D.L.S., Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

1.*D. C. TENNANT, B.A.Sc., Lachine Locks, Que.
With Dominion Bridge Co.

3. W. W. VANEVERY, Sault Ste Marie, Ont.
Soo Corporation.

3. W. E. WAGNER, B.A.Sc., Toronto, Ont.
With Toronto Ferry Co.

2. G. H. WATT, D.L.S., Ottawa, Ont.
Dominion Land Surveyor.

3. E. YEATES, Hamilton, Ont.
Manager, London Machine Tool Co., Ltd.

1900.

1. J. L. ALLAN, A.M. Can. Soc., C.E., Halifax, N.S.
Office of Provincial Engineer.

2. E. G. R. ARDAGH, B.A.Sc., Toronto, Ont.
Lecturer in Applied Chemistry, University of Toronto.

3. J. A. BAIN, Ottawa, Ont.
Structural Engineer, Dept. of Public Works of Canada.

3. J. H. BARLEY, B.A.Sc., Hamilton, Ont.
Canadian Westinghouse Co.

2.*M. C. BOSWELL, M.A., Ph.D., Toronto, Ont.
Lecturer in Organic Chemistry, University of Toronto.

1. L. T. BRAY, D. & O.L.S., Edmonton, Alta.
District Engineer and Surveyor.

3. J. CLARK, Pittsburgh, Pa.
Electrician, P. & L. E. R. R.

2. J. E. DAVISON, B.A.Sc., Fort William.
Engineering Staff, Can. Northern Ry.

3. E. D. DICKINSON, Schenectady, N.Y.
With General Electric Co.

3. G. W. DICKSON, B.A.Sc., Toronto, Ont.
With Smith, Kerry & Chace.

2.*H.A.DIXON, B.A.Sc., M.L.S., Winnipeg, Man.
Division Engineer, Canadian Northern Railway.

2. C. H. FULLERTON, O.L.S., New Liskeard, Ont.
Engineer and Surveyor.

3. W. S. GUEST, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.

3. W. HEMPHILL B.A.Sc., E.E., Buffalo, N. Y.
Superintendent, Cataract Power & Conduit Co.

3. S. E. M. HENDERSON, 422 Rubidge St., Peterboro, Ont.
Designing Engineer, Canadian General Electric Co.

3. J. A. HENRY, Schenectady, N. Y.
Designing Engineer, General Electric Co.,

2. H. S. HOLCROFT, B. A.Sc., D.L.S.
Surveyor, Peace River District.

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*Diploma with honours.

1900—*Continued.*

3. H. A. Johnson, 148 Clinton St., Toronto, Ont.
Manager, Johnston Oil Engine Co., Limited.
3. J. C. Johnston, Boston, Mass.
Plant Inspector, Warren Bituminous Paving Co.
2.*J. A. Johnston, B.A.Sc., Ignace, Ont.
Contractor.
2. R. E. McArthur, Montreal, Que.
Const. Dept., C.P.R.
2. J. G. McMillan, B.A.Sc., 39 Wood St., Toronto, Ont.
Mining Engineer.
3. L. Haun Miller, Cleveland, Ohio.
Sales Agent, Bethlehem Steel Co.
2. E. V. Neelands, B.A.Sc., Cobalt, Ont.
Hargrave Mines.
1.*E. H. Phillips, D.L.S., Saskatoon, Sask.
Phillips & Phillips, Civil Engineers and Surveyors.
2. J. R. Roaf, B.A.Sc., Michel, B.C.
Draftsman, Crow's Nest Pass Coal Co.
3.*C. H. E. Rounthwaite, Winnipeg, Man.
Draftsman, G.T.P. Ry.
2. H. W. Saunders, B.A.Sc., Gary, W. Va.
Division Engineer, U.S. Coal & Coke Co.
1. A. Taylor, D.L.S. & M.L.S.. Portage La Prairie, Man.
Engineer and Surveyor.
1. W. C. Tennant, B.A.Sc. (deceased).
2. S. M. Thorne, B.A.Sc., Cobalt, Ont.
Engineering Staff, Silver Leaf Mine.
1. F. W. Thorold, B.A.Sc., Toronto, Ont.
Assistant City Engineer on Const. of Sewage System.
1. H. M. Weir, B.A.Sc., Pachuca, Mex.
With Real Del Morte Co.
3. F. D. Withrow, Ottawa, Ont.
Patent Examiner, Dept. of Agriculture.

1901.

1. R. H. Barrett, B.A.Sc., O.L.S. (deceased).
3. W. G. Beatty, Fergus, Ont.
Manager, Beatty Bros., Implement Manufacturers.
3. G. M. Bertram, Joplin, Mo.
Representative of the Sullivan Machinery Co.
3. W. J. Bowers (deceased).
3. E. T. J. Brandon, B.A.Sc., Toronto, Ont.
Assistant Engineer Hydro-Electric Power Comm.
3. W. P. Brereton, B.A.Sc., Winnipeg, Man.
Assistant Engineer, Power Construction Dept.

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*Diploma with honours.

1901—*Continued.*

3. J. T. Broughton, Scottdale, Pa.
Chief Engineer, Scottdale Foundry & Machine Co.

3.*W. G. Chace, B.A.Sc., Carnegie Library, Winnipeg, Man.
Firm of Smith, Kerry & Chace.

3. A. G. Christie, 1713 Munro St., Madison, Wis.
Professor of Steam Engineering, University of Wisconsin.

3. J. R. Cockburn, B.A.Sc., A. M. Can. Soc. C.E. Toronto, Ont.
Lecturer in Descriptive Geometry, University of Toronto.

1. W. A. Duff, Ottawa, Ont.
Assistant Bridge Engineer, Transcontinental Ry.

2.*D. E. Eason, B.A.Sc., Peterboro', Ont.
Division Engineer, Trent Valley Canal.

1.*S. Gagne, B.A.Sc (deceased).

3. N. R. Gibson, B.A.Sc., Winnipeg, Man.
Assistant Engineer, Power Const. Dept.

2. A. T. E. Hamer, Wahnapitae, Ont.
Engineering Staff, Canadian Northern Ry. Co.

1. C. Harvey, B.A.Sc., D.L.S., Kelowna, B.C.
Consulting Engineer and Surveyor.

2. F. C. Jackson, La Tuque, Que.
Jackson & Connelly, Contractors, N.T.C. Ry.

3.*A. Laidlaw, Kansas, City, Mo.
District Manager, Trussed Concrete Steel Co.

3. W. C. Lumbers, Calgary, Alta.
Engineering Staff, C.P.R.

3. A. C. Macdougall, Massena, N.Y.
Asst. Superintendent, Aluminium Co. of America.

3. A. T. C. McMaster, B.A.Sc., Copper Cliff,
Engineer on Design & Construction, The Canadian Copper Co.

1. G. MacMillan, Ottawa, Ont.
Topographical Surveys Branch, Dept. of Interior.

3.*H. G. McVean, B.A.Sc., Moose Jaw, Sask.
Contractor and Engineer.

2. W. C. Matheson, Joliette, Que.
With McKenzie Mann. Co.

3. H. T. Middleton, Englewood Cliffs, N.J.

2. J. L. R. Parsons, B.A., D.L.S., Winnipeg, Man.
Engineer and Surveyor.

1. G. H. Power, North Battleford, Sask.
Western Canada Rep. of Willis Chipman, C.E.

3.*H. W. Price, B.A.Sc., Toronto, Cnt.
Lecturer in Electrical Engineering, University of Toronto.

1. H. P .Rust, B.A.Sc., A.M.Can. Soc., C.E., New York, N.Y.
With Messrs. Viele, Blackwell & Buck.

3. M. V. Sauer, B.A.Sc., Niagara Falls, Ont.
Assistant Engineer, Ontario Power Co.

3. W. H. Stevenson, B.A.Sc., Monadnock Block, Chicago, Ill.
Secretary Power Plant Specialty Co.

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*Diploma with honours.

1901—*Continued.*

1. R. D. WILLSON, Winnipeg, Man.
Assistant City Engineer.

1902.

3.*H. G. BARBER, Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

1. W. J. BLAIR, B.A.Sc., D. & O.L.S., New Liskeard, Ont.
Civil Engineer and Surveyor.

3. J. M. BROWN, Pittsburgh, Pa.
With Westinghouse Machine Co., Steam Turbine Dept.

2. W. G. CAMPBELL, Toronto, Ont.

2. A. R. CAMPBELL, Toronto, Ont.
Universal Mfg. Co., Ltd., St. James Chambers.

3. C. G. Carmichael (deceased).

2.*W. CHRISTIE, B.A.Sc., Prince Albert, Sask.
Dominion Land Surveyor.

2. F. T. CONLON, Thorold, Ont.
Welland Canal Engineering Staff.

3. H. V. CONNOR, Pittsburgh, Pa.
With Westinghouse Electric and Mfg. Co.

2.*M. T. CULBERT, deceased.

2. R.CUMMING, Toronto, Ont.
General Contractor. 50 Front St. E.

1. W. E. DOUGLAS, B.A., Toronto, Ont.
Contractor, 152 Bay St.

3.*R. J. DUNLOP, Toronto, Ont.
With Canadian Westinghouse Co.

2. W. M. EDWARDS, B.A.Sc., 1510 5th St. West, Calgary, Alta.
With Smith, Kerry & Chace.

3. W. ELWELL (deceased).

2. J. M. EMPEY, B.A.Sc.,O.L.S.,D.L.S., Calgary, Alta,
District Engineer and Surveyor, Dept. of Public Works.

2.*D. L. H. FORBES, Yzabal, Sonora, Mex.
Metallurgical Engineer El Tigre Mining Co.

1.*A. E. GIBSON, B.A.Sc., Toronto, Ont.
Office of Haney & Miller, Engineers and Contractors.

3. A. C. GOODWIN, Pittsburgh, Pa.
Draftsman, Aluminium Co. of America.

3. C. P. HENWOOD, McKeesport, Pa.
Draftsman, National Tube Co.

3. D. M. JOHNSTON, London, Ont.
Inspector, London Sub-station, Hydro-Electric Power Comm.

2. R. H. KNIGHT, B.A.Sc.,D.L.S., Edmonton, Alta.
Driscoll & Knight, Engineers and Surveyors.

5.*F. L. LANGMUIR, B.A.Sc.,Ph.D., Toronto, Ont.
Chemist, M. Langmuir Mfg. Co.

3. A. H. McBRIDE, B.A.Sc., Toronto, Ont.
Assistant Engineer, Hydro-Electric Power Commission.

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*Diploma with honours.

1902—*Continued.*

1. A. L. McLennan, D.L.S., Toronto, Ont.
Office of York Co. Engineer.

3. J. T. Mackay, Toronto, Ont.
Student in Faculty of Medicine, University of Toronto.

3. J. F. S. Madden, Winnipeg, Man.
Erecting Engineering Dept., Can. Gen. Electric Co.

3.*C. H. Marrs, Pittsburgh, Pa.
Designing Engineer, Riter-Conley Mfg. Co.

3. P. Mathison, B.A.Sc., Hamilton, Ont.
Electrical Eng., Canadian Westinghouse Co.

3. R. S. Mennie, Pittsburgh, Pa.
With Crucible Steel Co. of America.

2. H. H. Moore, D.L.S., A.M. Can. Soc. C.E., Calgary, Alta.
Dominion Land Surveyor and Engineer.

1.*T. S. Nash, Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

1. G. G. Powell, B.A.Sc., Toronto, Ont.
Asst. City Engineer, Roadways Dept.

1.*W. F. Ratz, D.L.S. (deceased).

3. H. D. Robertson, B.A.Sc., Toronto, Ont.
Miller, Cumming & Robertson, Engineers and Contractors.

3.*D. Sinclair, B.A.Sc. (deceased).

2.*I. J. Steele, D.L.S., Ottawa, Ont.
Topographical Surveys Branch, Dept. of Interior.

3. W. H. Sutherland, B.A.Sc., 107 St. James St., Montreal, Que.
Assistant Engineer, Montreal Water and Power Co.

3.*T. F. Taylor, 494 Concord Ave., Toronto, Ont.

2.*C. M. Teasdale, Concord, Ont.
Surveyor.

3. A. A. Wanless, Sydney Mines, N.S.
Lecturer, Sydney Mines Technical Schools.

3. H. J. Zahn, B.A.Sc., 235 Calumet St., Detroit, Mich.

1903.

3. H. G. Acres, Toronto, Ont.
Asst. Engineer, Hydro-Electric Power Commission.

1. J. G. R. Alison, Pittsburgh, Pa.
With Riter-Conley Mfg. Co.

3.*H. H. Angus, B.A.Sc., Bethlehem, Pa.
Draftsman, Bethlehem Steel Co.

3. J. A. Beatty, Peterboro', Ont.
Morrow & Beatty, Contractors.

3.*J. Breslove, East Pittsburgh, Pa.
Steam Turbine Engineer, Westinghouse Machine Co.

2. J. H. Burd, O.L.S., Sudbury, Ont.
Engineer and Surveyor.

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*Diploma with honours.

1903—*Continued.*

1.*E. L. Burgess, D.L.S., Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

2. N. A. Burwash, B.A.Sc., Whitehorse, Y.T.
Surveyor.

1. F. F. Clarke, D. & O.L.S. A.M. Can. Soc. C.E., Toronto, Ont.
Divisional Engineer, Can. Northern Ry.

2. C. L. Coulson, Welland, Ont.

3.*A. E. Davison, B.A.Sc., Toronto, Ont.
Engineering Staff, Hydro-Electric Power Commisssion.

3. C. J. Fensom, B.A.Sc., M.E., Toronto, Ont.
Consulting Mechanical Engineer, 43 Victoria St.

2.*E. O. Fuce, O.L.S., Galt, Ont.
Consulting Civil Engineer.

3*.F. A. Gaby, B.A.Sc., Toronto, Ont.
Assistant Chief Engineer, Hydro-Electric Power Commission.

1. J. C. Gardner, B.A.Sc., Niagara Falls, Ont.
City Engineer.

3. R. E. George, Dover, N.H.
Electrical and Gas Engineer, The United Gas & Electric Co.

1.*P. Gillespie. B.A.Sc., Toronto, Ont.
Lecturer in Theory of Construction, University of Toronto.

1. W. A. Gourlay, Toronto, Ont.
Engineering Staff, C.P.R.

2. J F. Hamilton, B.A.Sc., C.E., Lethbridge, Alta.
Hamilton & Young, Dominion Land Surveyors and Engineers.

2. G. S. Hanes, B.A.Sc, O.L.S. North Vancouver, B.C.
City Engineer.

2. F. Y. Harcourt, B.A., Port Arthur, Ont.
Engineer, Public Works Dept.

1. L. J. Hayes, Chicago, Ill.
Structural Engineer, Corn Products Refining Co.

1.*F. D. Henderson, Sec'y. Board of Examiners for D.L.S., Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

5.*J. A. Horton, New Ontario.

3. J. G. Jackson, Toronto Ont.
Electrical Department, City Hall.

3. C. K. Johnston, Pefferlaw, Ont.
Merchant.

1. H. Johnston, O.L.S., Berlin, Ont.
Davis & Johnston, Civil Engineers and Surveyors.

3. A. G. Lang, Toronto, Ont.
Underground Superintendent, Toronto Hydro-Electric System.

1.*A. J. Latornell, B.A.Sc., Edmonton, Alta.
City Engineer.

1.*H. J. McAuslan, B.A.Sc., O.L.S., North Bay, Ont.
Staff of T. & N.O. Ry.

3. J. A. McFarlane. B.A.Sc., Hamilton, Ont.
Chief Draftsman, Hamilton Bridge Works Co.

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*Diploma with honours.

1903—*Continued.*

1.*A. L. McNaughton, Prince Rupert, B. C.
With G.P.T. Co.

5.*F. G. Marriott, B.A.Sc., Toronto, Ont.
Chemist and Supt. Asphalt Plant, City Testing Laboratory.

3.*C. A. Maus, Paris, Ont.

3.*M. L. Miller, Pittsburg, Pa.
Draftsman, McClintic-Marshall Construction Co.

3. P. H. Mitchell, Toronto, Ont.
Consulting Electrical Engineer, Trader's Bank Building.

2.*R. H. Montgomery, B.A.Sc., O. and D.L.S., Prince Albert, Sask.
Engineer and Surveyor.

1. F. A. Moore, Winnipeg, Man.
Engineering Dept., C. N. Ry.

3. E. E. Mullins, Limon, Costa Rica, C.A.
Baldwin Locomotive Works.

3. I. H. Nevitt, B.A.Sc., Toronto, Ont.
Construction Bell Telephone Co.

1. E. W. Oliver, B.A.Sc., C.E., Toronto, Ont.
Assistant Chief Engineer, Canadian Northern Ry. System.

3. J. P. Oliver, Arabi, La.
Supt. of Construction, The American Sugar Refining Co.

3. J. D. Pace, B.A.Sc., Montreal, Que.
Construction Engineer, Canadian Westinghouse Co.

3. B. B. Patten, B.A.Sc., St. Catharines, Ont.
Rutherford & Patten, Engineers and Surveyors.

2. D. H. Philp, Ottawa, Ont.
Georgian Bay Canal Survey.

3.*D. H. Pinkney, Elyria, O.
National Tube Dept., U.S. Steel Corporation.

2. T. H. Plunkett, B.A.Sc., Toronto, Ont.

1. D. F. Robertson, D.L.S., Ottawa, Ont.

3.*H. M. Schiebe, B.A.Sc., East Pittsburgh, Pa,
Engineer, Westinghouse Electric & Mfg. Co.

1.*H. L. Seymour, Edmonton, Alta.
Sanders & Seymour, Civil Engineers and Dominion Land Surveyors.

1. J. H. Smith, D. & O.L.S., Edmonton, Alta.
Engineer and Surveyor, 140 Jasper Ave. W.

3. H. G. Smith, B.A.Sc., (deceased).

3. S. L. Trees, B.A.Sc., Toronto, Ont.
Supt. Mfg. Dept., Samuel Trees & Co., 42 Wellington St. East.

2. J. E. Umbach, Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

1. J. Waldron, D.L.S., Moose Jaw, Sask.
Engineer and Surveyor.

3.*S. B. Wass, Presque Isle, Me.
Chief Engineer, Amostook Valley Railroad.

3. J. A. Whelihan, Regina, Sask.

*Diploma with honours.

1903—*Continued.*

3. H. F. White, London, Ont.
Assistant Superintendent, The Geo. White & Sons Co., Ltd.
2.*C. G. Williams, B.A.Sc., Elk Lake, Ont.
Superintendent, Otisse Mining Co.
1.*N. D. Wilson, B.A.Sc., Lumsden Bldg., Toronto.
Engineer and Surveyor.
1.*C. R. Young, B.A.Sc., A.M. Can. Soc. C.E., Toronto, Ont.
Lecturer in Structural Engineering, University of Toronto.

1904.

3.*J. H. Alexander, B.A., St. Louis, Mo.
Engineer, Hunkins-Willis L. & C. Co.
3.*J. H. Barrett, Toronto, Ont.
With the Wm. Davies Co., Ltd.
3. M. B. Bonnell, Bobcaygeon, Ont.
3. T. D. Brown, B.A.Sc., Calgary, Alta.
Canadian Fairbanks Co.
3. F. W. Burnham, B.A.Sc., Milwaukee, Wis.
Steam & Electrical Department, Allis-Chalmers-Bullock Co.
3. J. W. Calder, B.A Sc., Fort William, Ont.
With Hydro-Electric Commission.
1. N. C. Cameron, 4172 Dorchester St., Montreal, Que.
Dominion Engineering and Construction Co.
1. A. J. Campbell, B.A.Sc., Toronto, Ont.
3.*A. M. Campbell, B.A.Sc., 1403 King St. W., Toronto, Ont.
4. J. B. Challies, Ottawa, Ont.
Hydraulic Engineer, Department of the Interior.
2. C. A. Chilver Walkerton, Ont.
2. H. L. Chilver, Moosehorn Bay, Man.
1. U. W. Christie, B.A.Sc., O.L.S., Ottawa, Ont.
Astronomical Surveys Branch, Dept. of the Interior.
2. P. C. Coates, B.A.Sc., Cobalt, Ont.
Mining Engineer.
1. S. B. Code, Smith's Falls, Ont.
Town Engineer.
1.*T. F. Code, B.A.Sc (deceased).
1.*W. A. Cowan, Farnham, Que.
Resident Engineer, C.P.R.
3.*S. E. Craig, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1.*S. R. Crerar, B.A.Sc., O.L.S., Toronto, Ont.
Lecturer in Surveying, University of Toronto.
3. W. M. Currie, Hamilton, Ont.
Managing Director, Canada Steel Co. Ltd.
3. H. H. Depew, Fernie, B.C.
Supt., Crow's Nest Pass Electric Light and Power Co.

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*Diploma with honours.

1904—*Continued.*

2. A. J. Elder, Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

2. J. G. Fleck, Vancouver, B.C.
Fleck Bros. Ltd.

1.*A. L. Ford, B.A.Sc., Prince Rupert, B.C.
Government Inspector on G.T.P. Ry.

3. W. S. Gibson, B.A.Sc., 38 Park Rd., Toronto, Ont.

1. J. N. Goodall, Toronto, Ont.

1. J. P. Gordon, Toronto, Ont.
Engineering Staff, Willis Chipman, C.E.

3. W. W. Gray, B.A.Sc., Toronto, Ont.
Lecturer in Mechanical Engineering, University of Toronto.

1. A. Gray, B.A.Sc., Port Credit, Ont.
With St. Lawrence Starch Co.,

3. W. K. Greenwood, B.A.Sc., Orillia, Ont.
Town Engineer.

1. L. D. Hara, St. Catharines, Ont.
Assistant Engineer, Welland Canal Co.

3. C. J. Harris, B.A.Sc., Brantford, Ont.
With Brantford Screw Co.

1. J. B. Heron, B.A.Sc., Toronto, Ont.
c. o. *S. H. Sykes, 1577 Danforth Ave.*

1. E. M. M. Hill, Winnipeg, Man.
Engineering Dept., Canadian Northern Railway.

2. S. N. Hill, 325, Waverly St., Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

2. C. J. Ingles, Niagara Falls, Ont.
With Ontario Power Co.

1. E. A. James, B.A.Sc., Toronto, Ont.
Managing Editor, Canadian Engineer.

1. P. V. Jermyn, B. A.Sc., 118 King St. West, Toronto, Ont.
C.P.R. Construction Department.

3. W. S. H. Keefe, Fort Covington, N.Y.
Manager, Light, Heat and Power Co.

3. W. J. Larkworthy (deceased).

3. O. B. McCuaig, B.A.Sc., Wenatchee, Wash.
Supt. ,Entiat Light and Power Co.

1. G. G. McEwen, B.A.Sc., Winchester, Ont.
Office of T. H. Dunn, O.L.S.

1.*W. G. McFarlane, B.A.,B.A.Sc.,
Engineer and Surveyor, Peace River Dist.

3.*C. P. McGibbon, B.A., East Pittsburgh, Pa.
With Westinghouse Electric and Mfg. Co.

3. C. McKay, B.A.Sc., (deceased).

1. D. McMillan, Woodville, Ont

3. G. J. Manson, Thorold, Ont.
With Manson Mfg. Co., Ltd.

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*Diploma with honours.

1904—*Continued.*

1.*W. N. Moorhouse, Toronto, Ont.
Office of Sproatt & Rolph, Architects.

3. E. E. Moore, Glen Falls, N.Y.
Engineer, Inter-State Iron Co.

3. W. H. Munro, Ottawa, Ont.
Assistant to J. B. McRae.

3. G. Pace, B.A.Sc., Hamilton, Ont.
With Canadian Westinghouse Co.

3. W. S. Pardoe, B.A.Sc., Philadelphia, Pa.
Instructor in Hydraulics, University of Pennsylvania.

3. J. Paris, La Tuque, Que.
Resident Engineer, Trans. Ry.

2. J. Parke, B.A.Sc., Havilah, Ont.
Chemist and Assayer.

3. W. J. Parker, Ottawa, Ont.
Top. Surveys Branch, Dept. of Interior.

3.*A. E. Pickering, Sault Ste. Marie, Ont.
Supt., Lake Superior Power Co.

1. D. L. C. Raymond, B.A.Sc., Toronto, Ont.
Manager, The Concrete Engineering and Construction Co., Ltd.

1. F. B. Reid, B.A.Sc., Ottawa, Ont.
Astronomical Surveys Branch, Dept. of the Interior.

3.*M. R. Riddell, B.A.Sc., Toronto, Ont.

3. G. S. Roxburgh, B.A.Sc., Winnipeg, Man.
Manager, Fetherstonhaugh & Co., Patent Solicitors and Engineers.

2. F. N. Rutherford, B.A.Sc., St. Catharines, Ont.
Rutherford and Patten, Surveyors and Engineers.

1.*J. D. Sheply, B.A.Sc., D.L.S., N. Battleford, Sask.
District Surveyor and Engineer.

3. F. W. Slater, B.A.Sc., Schenectady, N.Y.
With General Electric Co.

3.*R. S. Smart, Ottawa, Ont.
Manager, Fetherstonhaugh & Co., Patent Solicitors and Engineers.

1. D. A. Smith, B.A.Sc., Claude, Ont.

3. W. J. Smither, B.A.Sc., 50 St. Clair Ave., Toronto, Ont.

3. S.E. Thomson, B.A.Sc., Niagara Falls, Ont.
Engineering Staff, Electrical Development Co.

3. C. J. Townsend, B.A.Sc., Toronto, Ont.

1. D. T. Townsend, B.A.Sc., O.L.S., Winnipeg, Man.
C.P.R. Land Department.

1. A. V. Trimble, B.A.Sc., Toronto, Ont.
Hydro-Electric Power Commission.

3. B. B. Tucker, B.A.Sc., Morrisburg, Ont
Resident Engineer, New York and Ontario Power Co.

2.*E. Wade, B.A., Welland, Ont.
Teacher.

1.*E. W. Walker, B.A.Sc., (deceased).

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*Diploma with honours.

1904—*Continued.*

3. J. P. Watson, B.A.Sc., *Draftsman, Motive Power Dept., C.P.Ry.*	Montreal, Que.
1. J. M. Weir, *Engineering Staff, G.T. Ry.*	Hamilton, Ont.
1.*A. F. Wells, O.L.S.,B.A.Sc., *Wells & Gray, Ltd., Engineers and Contractors.*	Toronto, Ont.
1. W. R. Worthington, B.A.Sc., *Assistant Sewer Engineer, Staff of City Engineer.*	Toronto, Ont.
3. W. F. Wright, *Sales Dept., Canadian General Electric Co.*	Toronto, Ont.

1905.

2. H. W. Arens, (deceased).	
3. R. H. Armour, *Westinghouse Electric & Manufacturing Co.*	165 Broadway, New York.
3.*C. B. Aylesworth, *Draftsman, Canadian Westinghouse Co.*	Hamilton, Ont.
1.*W. Barber, B.A.Sc., *Roadways Department, City Hall.*	Toronto, Ont.
2.*W. A. Begg, B.A.Sc., *Department of Public Works.*	Regina, Sask.
3.*G. G. Bell, *Canadian Bridge Co.*	Walkerville, Ont.
1. J. C. Boeckh, *With Boeckh Brush Co.*	Toronto, Ont.
3. W. M. Bristol, *Canadian Westinghouse Co.*	Halifax, N.S.
2. W. C. Campbell, *Mining Engineer.*	Keene, Ont.
3. W. R. Carson, *Construction Engineer, Taylor Iron and Steel Co.*	High Bridge, N.J.
1. A. V. Chase,	Orillia, Ont.
3. S. R. A. Clement, *With Hydro-Electric Power Commission.*	Toronto, Ont.
3. T. E. Corrigan, *Chief Electrician, Standard Consolidated Mining Co.*	Bodie, Cal.
1.*N. L. R. Crosby, B.A.Sc., *Assistant Contracting Engineer, McClintic-Marshall Const. Co.*	Chicago, Ill.
1. G. H. Ferguson, B.A.Sc., *Hydro-Electric Commission.*	Toronto, Ont.
3. H. S. Fierheller, B.A.Sc. (deceased).	
3. F. W. Harrison, *Chief Mechanical Draftsman, Edison Electric Illuminating Co.*	360 Pearl St., Brooklyn, N.Y.
1. M. C. Hendry, B.A.Sc.,	Toronto, Ont.
2. C. S. L. Hertzberg, *Trussed Concrete Steel Co.*	Walkerville, Ont.

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*Diploma with honours.

1905—*Continued.*

3. W. G. Hewson, B.A.Sc., *With Smith, Kerry and Chace.*	Toronto, Ont.
1. G. S. Jones,	Smith's Falls, Ont.
3.*G. Kribs, *With Smith, Kerry and Chace.*	Toronto, Ont.
2. P. A. Laing, *Resident Engineer, T.C. Ry.*	Fanquier, Ont.
1. A. Latornell, B.A.Sc., *Sewer Department, City Hall.*	Toronto, Ont.
3. J. W. Leighton, *Secretary, Evans Rotary Engine Co.*	Toronto, Ont.
1.*T. R. Loudon, B.A.Sc., *Lecturer in Metallurgy, University of Toronto.*	Toronto, Ont.
3. S. E. McGorman, *Draftsman, Canadian Bridge Co.*	Walkerville, Ont.
1.*W. W. McGregor (deceased).	
2. D. W. McKenzie, *Draftsman, Engineering Dept., C.N. Ry.*	Winnipeg, Man.
3.*C. A. McLean, *Canadian Westinghouse Co.*	Toronto, Ont.
2. W. N. McLean.	Erin, Ont
3. F. G. Mace, *Patent Examiner, Dept. of Agriculture.*	Ottawa, Ont.
3. R. W. Moffatt, B.A.Sc., *Demonstrator in Drawing, University of Toronto.*	Toronto, Ont.
3. L. W. Morden, *Canadian Westinghouse Co.*	Toronto, Ont.
3. G. R. Munro, B.A.Sc., *With Hudson Bay Survey.*	Peterboro', Ont.
3.*W. G. Nicklin, B.A.Sc., *Assistant Superintendent, Dalnu & Kiefer Tanning Co.*	Front & Tetellier Sts., Grand Rapids, Mich.
1. E. D. O'Brien, *With Transcontinental Ry.*	Nipigon, Ont.
1.*B. B. Patten, B.A.Sc., *Rutherford and Patten, Surveyors and Engineers.*	St. Catharines, Ont.
1.* E. P. A. Phillips, B.A.Sc., O.L.S., *Pierce & Phillips, Engineers & Surveyors.*	Porcupine, Ont.
1. W. B. Porte,	Oakville, Ont.
2. E. F. Pullen, *Resident Engineer, Transcontinental R.R.*	Cochrane, Ont.
2. G. L. Ramsey, B.A.Sc.,	Dunnville, Ont.
1. G. W. Rayner,	Thorold, Ont.
3.*R. B. Ross, (deceased).	
5. T. E. Rothwell, B.A.Sc., *Provincial Assay Office.*	Belleville, Ont.
2.*G. S. Scott, *Fellow in Mineralogy, University of Toronto.*	Toronto, Ont.

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*Diploma with honours.

1905—*Continued.*

3. H. V. Serson, Highbridge, N.J.
Engineer in charge, Power House Const., Taylor Iron & Steel Co.

3. C. H. Shirriff, B.A.Sc., Toronto, Ont.
Chemist, Imperial Extract Company.

3.*C. E. Sisson, Peterboro', Ont.
Engineering Department, Canadian Gen. Electric Co.

1. D. L. N. Stewart, B.A.Sc., Collingwood, Ont.

1. M. A. Stewart, Toronto, Ont.
Assistant City Engineer, Roadway Dept., City Hall.

3.*W. F. Stubbs, Galt, Ont.
Assistant Engineer, Goldie & McCulloch Co.

1. N. H. Sturdy, Cleveland, Ohio.
Designer, L, S. & M. S. Ry.

1. W. G. Swan, B.A.Sc., Langley, B.C.
Divisional Engineer, C. N. Ry.

1.*F. H. Sykes, O.L.S., D.L.S., Toronto, Ont.
Asst. Structural Engineer, with City Architect, City Hall.

3. L. R. Thomson, B.A.Sc., Winnipeg, Man.
Lecturer in Civil Engineering, University of Manitoba.

3. E. D. Tillson, B.A.Sc., New York, N.Y.
Engineer for Const. Dept., Safety Insulated Wire & Cable Co.

1.*J. J. Traill, B.A.Sc., Toronto, Ont.
Lecturer in Mechanical Engineering, University of Toronto.

1.*W. M. Treadgold, B.A., Toronto, Ont.
Lecturer in Surveying, University of Toronto.

3. W. E. Turner, B.A.Sc., Salt Lake City, Utah.
With Utah Light & Ry. Co.

3. A. E. Uren, Toronto, Ont.
Editor, Acton Publishing Co.

3. J. M. Vaughan, 58 Melville Ave., Toronto, Ont.
Contractor.

1. H. L. Wagner, B.A.Sc., Hamilton, Ont.
Draftsman, Hamilton Bridge Works Co.

2. W. H. Young, B.A.Sc., D.L.S., Lethbridge, Alta.
Hamilton & Young, Dominion Land Surveyors and Engineers.

1906.

1. F. Alport, Superior Junct., Ont.
Resident Engineer, Transcontinental Ry.

3.*W. L. Amos, Guelph. Ont.

1. A. H. Arens, Inverness, N.S.
Resident Engineer, Inverness Ry. & Coal Co.

3.*J. C. Armer, B.A.Sc., Toronto, Ont.
Secretary and Managing Editor of the Canadian Manufacturer Pub. Co. Ltd.

1. M. H. Baker, B.A.Sc., St. Thomas, Ont.
Assistant City Engineer.

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*Diploma with honours.

1906—*Continued.*

3. F. W. Baldwin, Baddeck, N.S.
With Graham Bell, Esq.

2. E. W. Banting, B. A.Sc., Toronto, Ont.
Demonstrator in Surveying, University of Toronto.

3. F. Barber, B.A., Toronto, Ont.
York County Engineer, 57 Adelaide St. E.

2. M. Bates, B.A.Sc (deceased).

2. J. P. Bellisle, (deceased).

3.*H. H. Betts, B.A.Sc., Rio de Janiero, Brazil.
Rio de Janiero Tramway, Light & Power Co.

5.*D. E. Beynon, B.A.Sc., Toronto, Ont.
With Dunlop Rubber Goods Co.

2. G. W. Bissett, Naughton, Ont.
Mill Supt., Canadian Exploration Co., Ltd.

3. W. C. Blackwood, B.A.Sc., Toronto, Ont.
Demonstrator in Physics, University of Toronto.

3. H. E. Brandon, B.A.Sc., Winnipeg, Man.
Chief Engineer, Vulcan Iron Works.

1. M. E. Brian, B.A.Sc., O.L.S., A.M. Can. Soc. C.E., Windsor, Ont.
City Engineer.

2. T. W. Brown, B.A.Sc., D. & S.L.S., Saskatoon, Sask.
Civil Engineer.

1.*A. E. K. Bunnell, B.A.Sc., Weyburn, Sask.
Engineering Staff, Willis Chipman, C.E.

3. F. M. Byam, Toronto, Ont.
With Smith, Kerry, and Chace.

3. A. Cameron, Toronto, Ont
Draftsman, Canada Foundry Co.

3. A. W. Campbell, B.A.Sc., Toronto, Ont.
Inspector, Hydro-Electric Power Commission.

1. M. J. Carroll, Ottawa, Ont.
Topographical Surveys Branch, Department of the Interior.

3.*R. E. C. Chadwick, Toronto, Ont.
Staff of City Engineer.

1.*G. T. Clark, B.A., Saskatoon, Sask.
City Engineer.

3.*G. A. Colhoun, Hamilton, Ont.
Draftsman, The Hamilton Bridge Works Co., Ltd.

1.*W. A. M. Cook, B.A.Sc., Toronto, Ont.
Staff of City Architect, City Hall.

1.*E. L. Cousins, B.A.Sc., Toronto, Ont.
Resident Engineer, G. T. Ry., Middle and Southern Div.

4. A. G. Creighton, Prince Albert, Sask.
Creighton & McConnell, Architects and Structural Engineers.

4. W. N. Daniels, 1215 Filbert St., Philadelphia, Pa.
With John R. Wiggins & Co.

3.*N. P. F. Death, B.A.Sc. 25 Jarvis St., Toronto, Ont.
Death & Watson, Electrical Engineers and Contractors.

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*Diploma with honours.

1906—*Continued.*

3. C. S. DUNDASS, B.A.Sc. Lachine, Que.
With Dominion Bridge Co.

3. S. L. FEAR, Amherstburg, Ont.
With Dunbar, Sullivan Dredging Co.

5.*C. C. FORWARD, Ottawa, Ont.
Laboratory of the Inland Revenue Department.

5. C. W. GRAHAM, B.A.Sc., Toronto, Ont.
Industrial Chemist, Wm. Davies Co.

1.*P. W. GREENE. Toronto, Ont.
With Hydro-Electric Power Commission.

3. C. B. HAMILTON, B.A.Sc., 43 Madison Ave., Toronto, Ont.
Hamilton Gear and Machinery Co.

1.*A. L. HARKNESS, B.A.Sc., Lachine Locks, Que.
With Dominion Bridge Co., Ltd.

1.*R. L. HARRISON, Cobourg, Ont.
Resident Engineer, Canadian Northern Ry.

1. E. HARRISON, B.A.Sc., New Liskeard, Ont.
With Sutcliffe & Neelands.

3. J. C. HARTNEY, B.A.Sc., Vancouver, B.C.
Engineer & Salesman, Canadian Westinghouse Co.

1. S. HETT, B.A.Sc., Sutton West, Ont.
Surveyor.

3. C. R. HILLIS, Toronto, Ont.
With Toronto & Niagara Power Co.

3. C. W. HOOKWAY, B.A.Sc., Winnipeg, Man.
Allis-Chalmers Bullock Co.

3. R. H. HOPKINS, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.

1.*R. S. HOUSTON, Emerson, Man.

2.*W. Huber, Toronto, Ont.
With Canadian Inspection Co.

3.*A. H. HULL, B.A.Sc., Toronto, Ont.
With Smith, Kerry and Chace.

3. W. C. JEPSON, Niagara Falls, Ont.
Welland Canal Office.

1.*C. JOHNSTON, B.A.Sc., Toronto, Ont.
District Engineer, Can. Northern Ry.

1. G. R. JONES, B.A.Sc., China.
Missionary.

3. T. JONES, B.A.Sc., 18 Meredith Crescent, Toronto, Ont.

1.*A. E. JUPP, B.A.Sc., Haileybury, Ont.

3. J. D. KEPPY, Toronto, Ont.
Canadian Inspection Co.

1. J. L. LANG, B.A.Sc., D. & O.L.S., Sault Ste. Marie, Ont.
Lang & Keys, Engineers and Surveyors.

3. A. P. LINTON, B.A.Sc., Montreal Que.
With Dominion Bridge Co.

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*Diploma with honours.

1906—*Continued.*

4.*A. Wellesley McConnell, B.A.Sc., Toronto, Ont.
Lecturer in Architecture, University of Toronto.

3.*D. G. McIlwraith, Galt, Ont.
Draftsman, The Goldie & McCulloch Co., Ltd.

2. J. A. McKenzie, Cobalt, Ont.
Manager, Nipissing Reduction Co.

1.*J. V. McNab, Kenora, Ont.
Transitman, C.PR. Engineering Staff.

3. J. A. McPherson, Toronto, Ont.
Student, Faculty of Medicine, University of Toronto.

2. K. A. MacKenize, B.A.Sc., Toronto, Ont.
Managing Editor, "Builder & Contractor."

1. W. MacKinnon, Rankin, Pa.
Erection Dept., McClintic Marshall Construction Co.

3.*W. Maclachlan, B.A.Sc., Belleville, Ont.
Trenton Electric and Waterpower Co.

3.*D. W. Marrs, Pittsburg, Pa.
Designer and Estimator, Riter-Conley Mfg., Co.

3. W. A. Maxwell, Walkerville, Ont.
Draftsman, Canadian Bridge Co.

1.*Rev. J. Mellon Menzies, B.A.Sc., D.L.S., North Honan, China.
Missionary, Wu An

3. L. R. Miller, B.A.Sc., Orillia, Ont.

1.*B. F. Mitchell, B.A.Sc., Edmonton, Alta.
Municipal Engineer.

1. F. F. Montague, 506 Union Bank Bldg., Winnipeg, Man.
Law Student.

1.*W. J. Moore, O.L.S., Pembroke, Ont.
Morris and Moore, Land Surveyors and Architects.

1. C. R. Murdock, Weyburn, Sask.

2. C. J. Murphy, B.A.Sc., Fernie, B.C.
Assistant Engineer, Crow's Nest Pass Coal Co.

1.*W. P. Near, B.A., B.A.Sc., Toronto, Ont.
Staff of City Engineer.

2. R. Neelands, Port Hammond, B.C.

3. D. G. Park, B.A.Sc., West Allis, Wis.
With Allis-Chambers-Bullock Co.

3. G. W. Paterson, Vancouver, B.C.
Salesman, Canadian Financiers, Ltd.

5. R. E. Pettingill, Port Colborne, Ont.
Chief Chemist, Portland Cenemt Co.

2.*R. C. Purser, B.A.Sc., Windsor, Ont.

3. N. R. Robertson, B.A.Sc., Walkerton, Ont.

1. J. O. Roddick, B.A.Sc., Toronto, Ont.
Assistant Engineer, Dept. of Public Works of Canada.

1. C. H. Rogers, B.A.Sc. Peterboro' Ont.
Peterboro Canoe Co.

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*Diploma with honours.

1906—*Continued.*

2.*O Rolfson, B.A.Sc., D.L.S., Peace Kiver District.
Dominion Land Surveyor.

1. R. C. Ross, B.A.Sc., Ottawa, Ont.
Department of the Interior.

1. K. G. Ross, Sault Ste. Marie, Ont.
With Lang & Keys, Engineers and Surveyors.

1.*H. T. Routly, O.L.S., D.L.S., Haileybury, Ont.
Routly, Summers & Malcolmson, Engineers. amd Surveyors.

2. J. H. Ryckman, Chicago, Ill.
Bridge and Bldg. Dept., Chicago Milwaukee & St. Paul Ry.

3.*W. K. Sanders, 58 Webster St., West Newton, Mass.

1.*W. A. Scott, B.A.Sc., D.L.S., Galt, Ont.
Dominion Land Surveyor.

1.*W. M. Stewart, B.A.Sc., 142 Aberdeen Ave., Hamilton, Ont.

2. J. E. Thomson, B.A.Sc., W. Virginia, U. S. A.
With Sterling Coal Co.

3.*C. L. Vickery, 112 Barlow St., Fall River, Mass.
Chief Engineer, American Thread Co.

5. W. E. Wickett (deceased).

3.*J. N. Wilson, B.A.Sc., Toronto, Ont.
Electrical Dept., City of Toronto.

3*E. M. Wood, B.A.Sc., 136 Lee Ave., Toronto, Ont.

1907.

3.*F. G. Allen, B.A.Sc., Hyde Park, Mass.
Assistant to Chief Engineer, B.F. Sturtevant Co.,

1. F. J. Anderson, B.A.Sc., Niagara Falls, Ont.

1. A. P. Augustine, Vancouver, B.C.
B. C. Land Surveyor.

3.*H. D. Bowman, B.A.Sc., Niagara Falls, Ont.
With the Ontario Power Co.

3. W. S. Brady, B.A.Sc., Toronto, Ont.

1. G. H. Broughton, Penticton, B.C.

1. J. A. Brown, B.A.Sc., Toronto, Ont.
Fellow in Drawing, University of Toronto.

1. C. E. Bush, B.A.Sc., 285 College St., Toronto, Ont.

3. J. H. Caster, Peterboro', Ont.
Production Dept. Can. Gen. Elec. Co.

1.*E. Cavell, Saskatoon, Sask.
Wiggins & Cavell, Surveyors and Engineers.

1.*C. B. B. Connell, Glasgow, Scotland.
With Mirrless & Watson.

3.*G. C. Cowper, B.A.Sc., Frankford, Ont.
Trent Valley Canal.

2. J. V. Culbert, B.A.Sc., Toronto, Ont.
Staff of Willis Chipman, C.E.

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*Diploma with honours.

1907—*Continued.*

3.*R. S. Davis, B.A.Ss., Calgary, Alta.
Sales Engineer, Canadian Westinghouse Co.

3. S. D. Evans, B.A.Sc., Leamington, Ont.

3.*F. R. Ewart, B.A.Sc., Toronto, Ont.

1. G. R. S. Fleming, Toronto, Ont.
With Atwell Fleming Printing Co.

6. P. C. Fux, B.A.Sc., Brantford, Ont.
With Waterous Engine Works Co.

1. J. S. Galletly, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

2. G. Galt, B.A.Sc., East Ely, Nevada.
With Nevada Co.

1. A. B. Garrow, B.A.Sc., Toronto, Ont.
Staff of City Engineer.

1. A. Gillies, B.A.Sc., Fort William, Ont.

1. G. W. Graham, Eugenia, Ont.

3. C. S. Grasett, B.A.Sc., 8 Harbord St., Toronto, Ont.

1.*R. E. W. Hagarty, B.A.Sc., Toronto, Ont.
Demonstrator in Drawing, University of Toronto.

3. K. Hall, B.A.Sc., 39 Sherman Ave., Hamilton.

1. C. T. Hamilton, B.A.Sc., Niagara Falls, Ont.
With Ontario Power Co.

3. R. A. Hare. St. Catharines, Ont.

3.*H. O. Hill, B.A.Sc., Pittsburgh, Pa.
With Riter-Conley Mfg. Co.

1.*T. H. Hogg, B.A.Sc., Niagara Falls, Ont.
Assistant to Supt. of Construction, Ontario Power Co.

3.*C. H. Hutton, B.A.Sc., Hamilton, Ont.
Engineering Staff, Dominion Power Co.

1. H. M. Hyland, B.A.Sc., 72 St. Mary St., Toronto, Ont.

3. E. W. Hyman, B.A.Sc., London, Ont.
Assistant Superintendent, London Electric Co.

3.*L. G. Ireland, B.A.Sc., Belleville, Ont.
Supt., Midland Construction Co., Ltd.

1.*W. Jackson, B.A.Sc., Niagara Falls, Ont.
With Ontario Power Co.

4.*C. B. Jackson, Chicago, Ill.
Estimating Dept. E. Everett Clora Co.

3.*E. W. Kay, B.A.Sc., Winnipeg, Man.
Salesman, Canadian Westinghouse Co.

3. D. F. Keith, Provo, Utah.
Electrical Engineer, Telluride Power Co.

1. H. P. Keith Comber, Ont.

1. A. A. Kinghorn, B.A.Sc., Toronto, Ont.
Inspector of Road ways,City Engineers Department.

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*Diploma with honours.

1907—*Continued.*

1. L. W. Klingner 568 Spadina Ave., Toronto, Ont.

1.*F. C. Lamb, B.A.Sc., North Battleford, Sask.
Department of Public Works.

3. A. D. LePan, B.A.Sc., Toronto, Ont.
Assistant Superintendent of Buildings and Grounds, University of Toronto.

1. J. H. Lindsay. Toronto, Ont.
Fellow in Surveying, University of Toronto.

3. J. A. D. McCurdy, Hammondsport, N.Y.
With Graham Bell, Esq.

1.*J. B. McFarlane, B.A.Sc., 60 Lonsdale Rd., Toronto, Ont.
Dominion Land Surveyor.

3.*D. J. McGugan, B.A.Sc., Vancouver, B.C.
With Humphreys & Tupper, Civil Engineers and Surveyors.

3. A. H. McIntosh, Chicago, Ill.
With Illinois Steel Co.

3. F. W. McNeill, B.A.Sc., Peterboro', Ont.
Canadian General Electric Co.

1.*M. K .McQuarrie, Vancouver, B.C.
Terminal Engineer, C.P. Ry. Co.

1.*G. MacLeod, Montreal, P.Q.
Assistant Secretary, Can. Soc. C.E.

1. A. G. Mackay, New York, N.Y.
With Hudson & Manhattan Ry. Co.

1. W. S. Malcolmson, B.A.Sc., Haileybury, Ont.
Routly, Summers & Malcolmson, Engineers and Surveyors.

3. S. A. Marshall, Snelgrove, Ont.

6. D. H. C. Mason, B.A.Sc., Toronto, Ont.

1. J. W. Melson, B.A.Sc., Toronto, Ont.
Fellow in Drawing, University of Toronto.

1. G. G. Mills, B.A.Sc., Toronto, Ont.

3. J. B. Minns, B.A.Sc., Peterboro', Ont.
Canadian General Electric Co.

4.*G. N. Molesworth, Toronto, Ont.
Draftsman, Eden Smith & Son, Architects.

1. J. M. Moore, B.A.Sc., London, Ont.
With McClary Mfg. Co.

5.*P. F. Morley, 177 Pearson Ave., Toronto, Ont.

1. E. W. Murray, Stratford, Ont.
Engineer, with Edge & Gutteridge, Contractors and Builders.

3. J. D. Murray, Toronto, Ont.
With Fetherstonhaugh & Co., Patent Solicitors and Engineers.

1. E. W. Neelands, B.A.Sc., New Liskeard, Ont.
Sutcliffe & Neelands, Consulting Engineers.

1. R. E. K. Neelands, B.A.Sc., Brampton, Ont.

2.*B. Neilly, B.A.Sc., Cobalt, Ont.
Assayer, Black Consolidated.

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*Diploma with honours.

1907—*Continued.*

1. A. E. Nourse, B.A.Sc., Toronto, Ont.
Assistant Engineer, Expanded Metal Co.

3. J. J. O'Sullivan, Toronto, Ont.
With Canada Railway News Co.

2. T. K. Paton, Wardner, Ida.
Mining Engineer.

1. F. W. Paulin, O.L.S., Niagara Falls, Ont.
Civil Engineer.

1. R. B. Potter, Toronto, Ont.
Post-Graduate course in Engineering. University of Toronto.

3.*F. E. Prochnow, B.A.Sc., Buffalo, N.Y.
With Wilhelm, Parker & Ward, Patent Attorneys.

3.*J. F. Procunier, Bayham. Ont.

3. G. E. Quance, B.A.Sc., Delhi, Ont.

3.*H. Raine, Hamilton, Ont.
With Hamilton Bridge Works Co.

1.*J. L. Rannie, B.A.Sc., Ottawa, Ont.
Observer, Geodetic Survey.

3. C. W. B. Richardson, B.A.Sc., Montreal, Que
Motive Power Dept., Angus Shops.

1. A. A. Ridler, Toronto, Ont.
Supt., Constructing & Paving Co., Ltd.

5. H. E. Rothwell, Port Richmond, N.Y.
Assistant Chemist, Standard Varnish Works.

5. C. A. Schofield, Buffalo, N.Y.
Chemist, Schoell-Kopf-Hartford & Hanna Co.

1.*A. C. T. Sheppard, Ottawa, Ont.
Department of Mines.

1. F. R. Smith, B.A. Gowganda, Ont.
Manager, Can. Gowganda Silver Mines.

3. E. R. Smithrim, B.A.Sc., Sault Ste., Marie, Ont.
With Tagona Water and Light Co.

1.*W. Snaith, Toronto, Ont.
Assistant Engineer, Barber & Young.

3. A. C. Spencer, B.A.Sc., London, Ont.
Mechanical Engineer, McClary Mfg. Co.

3. G. S. Stewart, Toronto, Ont.
Agent, Canadian General Electric Co.

1. J. A. Stiles, B.A.Sc., Toronto, Ont.
Demonstrator in Drawing, University of Toronto.

3.*J. L. Stiver, Ottawa, Ont.
Electrical Standard Laboratory, Inland Revenue Department.

1. J. L. G. Stuart, B.A.Sc., Toronto, Ont.
Railway and Special Works Department, City Hall.

1. G. F. Summers, O.L.S., Haileybury, Ont.
Routly, Summers & Malcolmson, Engineers and Surveyors.

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*Diploma with honours.

1907—*Continued.*

1.*H. W. SUTCLIFFE, New Liskeard, Ont.
Sutcliffe & Neelands, Consulting Engineers.

1. P. M. THOMPSON, B.A.Sc., Ambridge, Pa.
Draftsman, American Bridge Co.

3. O. R. THOMSON, B.A.Sc., Berlin, Ont.
Inspector, Hydro-Electric Power Commission.

1. L. R. THOMSON, B.A.Sc., Winnipeg, Man.
Lecturer in Civil Engineering, University of Manitoba.

1. W. J. WALKER, Nipigon, Ont.
With Transcontinental Ry.

1. E. D. WILKES, B.A.Sc., Toronto, Ont.
Main Drainage Department, City Hall.

3. A. F. WILSON, B.A.Sc., Chicago, Ill.
Inspector, Ghicago, Telephone Co.

3. M. H. WOODS, Toronto, Ont.
Post-Graduate Course in Engineering, University of Totonto.

1. G. W. A. WRIGHT, 517 Oxford St., London, Ont.
Warren Bituminous Paving Co.

3.J. YOUNG, Toronto, Ont.
Inspector, Canadian Fire Underwriter's Association.

3.*A. R. ZIMMER, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.

1908.

3. H. G. AKERS, B.A.Sc., Toronto, Ont.
Demonstrator in Electrochemistry, University of Toronto.

3. L. F. ALLAN, Toronto, Ont.
Roadway Dept., City Hall.

1.*C. B. ALLISON, South Woodslee, Ont.

1.*R. M. ANDERSON, B.A.Sc., Burlington, Ont.

5. J. R. ARENS, Toronto, Ont.
Post -graduate Course in Engineering, University of Toronto.

3. H. C. BARBER, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. E. BARTLETT, B.A.Sc., Smithville, Ont.
Dominion Land Survey Work.

2. F. J. BEDFORD, Porcupine, Ont.

1.*G. G. BELL, Portland, Me.
With Sawyer & Moulton, Consulting Engineers.

3. G. E. BLACK, B.A.Sc., Toronto, Ont.
Public Works Department of Ontario.

3. H. F. BOWES, Toronto, Ont.
Superintendent of Warren Bituminous Paving Co., Ltd.

3.*J. H. BRACE, Brooklyn, N.Y.
With N.Y. Telephone Co.

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*Diploma with honours.

1908—*Continued.*

1. P. R. Brecken, B.A.Sc., Montreal, Que.
General Secretary, Y.M.C.A.
3. E. I. Brown, Nipissing, Ont.
Assistant Engineer on Const. Can. Westinghouse Co., Nipissing Power Company.
1. W. F. M. Bryce, Ottawa, Ont.
Assistant Engineer, City Engineer's Department.
3. P. H. Buchan, B.A.Sc., Vancouver, B.C.
Engineering Department, B.C. Electric Ry. Co., Ltd.
2. J. E. Campbell, B.A.Sc., Copper Cliff, Ont.
Canadian Copper Co.
3. N. A. Campbell, Calgary. Alta.
Chief Chemist, Canada Cement Co.
3. A. M. Carroll, Cobalt, Ont.
Manager, Rochester Cobalt Mines, Ltd.
1. H. R. Carscallen, B.A.Sc., Calgary, Alta.
Assistant Hydrographer, with P. M. Sauder.
3. G. Challen, Goderich, Ont.
1. F. H. Chesnut, B.A.Sc., Mount Lebanon, B.C.
Resident Engineer, C.N.R. Plant.
1. W. E. Cole (deceased).
4.*W. C. Collett, B.A.Sc., Toronto, Ont.
Draftsman, F. S. Baker Trader's Bank Bldg.
1. R. Y. Cory, B.A.Sc., 530 Huron St., Toronto, Ont.
3.*H. Coyne, B.A.Sc.. 5930 South Park Ave., Chicago, Ill.
Designing Draftsman.
2.*J. D. Cumming, B.A.Sc., Copper Cliff, Ont.
6. A. D. Dahl, B.A.Sc., Midland, Mich.
Chemist, Dow Chemical Co.
1. F. A. Danks, Box 230, Penticton, B.C.
3. J. Darroch, Detroit, Mich.
Draftsman, Autoparts Mfg. Co.
3. H. C. Doorly, 6 McClellan St., Schenectady, N.Y.
2. R. H. Douglas, Edmonton, Alta.
Department of Public Works,
2.*F. C. Dyer, B.A.Sc., Toronto, Ont.
Demonstrator in Mining, University of Toronto.
1. F. M. Eagleson, Gorrie, Ont.
1. C. Edwards. B.A.Sc., Toronto, Ont.
With Standard Sanitary Mfg. Co.
1. S. L. Evans, B.A.Sc., Corinth, Ont.
1. E. O. Ewing, Campbellford, Ont.
1. O. L. Flanagan, B.A.Sc., Toronto, Ont.
With C. H. Mitchell, Consulting Engineer, 1003 Traders' Bank Bldg.
1. C. Flint, B.A.Sc., Monadnock, B.L., Chicago.
With MacDonald Engine Co.

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*Diploma with honours.

1908—*Continued.*

1. A. H. Foster, B.A.Sc., Toronto, Ont.
3. G. C. Francis, Toronto, Ont.
City Engineer's Staff, Roadway's Department.
3. S. S. Gear, Fort Erie.
1. C. A. Grassie, B.A.Sc., Welland, Ont.
3.*C. L. Gulley, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.
3. J. W. Hackner, B.A.Sc., Nairn Centre, Ont.
Inspector of Public Works.
3. F. L. Haviland, Hamilton, Ont.
Draftsman, Hamilton Bridge Works Co.
1.*C. D. Henderson, Walkerville, Ont.
Canadian Bridge Co.
5.*D. J. Huether, B.A.Sc., Plainfield, N.J.
Manager, Century Rubber Trading Co.
1. A. D. Huether, B.A.Sc., 77 Grenville St., Toronto, Ont.
3.*A. N. Hunter, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.
3. S. B. Iler, Belleville, Ont.
Construction Department, Seymour Power & Electric Co.
1.*J. T. Johnston, B.A.Sc., Campbellford, Ont.
Assistant Engineer on Construction of Trent Canal.
2. H. G. Kennedy, Toronto, Ont.
Post Graduate Course in Engineering, University of Toronto.
1.*W. R. Keys, Winchester, Ont.
3.*J. N. M. Leslie, B.A.Sc., Hamilton, Ont.
With Canadian Westinghouse Co.
3. F. C. Lewis, Chicago, Ill.
American Bridge Co.
3. H. R. Lynar, Toronto, Ont.
Lynar & Mace, Consulting Engineers.
1.*W. G. McGeorge, Chatham, Ont.
Consulting Engineer.
1. J. M. McGregor, Ridgetown, Ont.
1. L. A. McLean, B.A.Sc., (deceased).
1. W. A. A. McMaster, Palmerston, Ont.
1. H. C. McMordie, B.A.Sc., Walkerville, Ont.
With Canadian Bridge Co.
1.*A. A. McRoberts, B.A.Sc., Pontypool, Ont.
Assistant on Dominion Land Survey.
5.*N. G. Madge, New York, N. Y.
Chief Chemist, Continental Rubber Co. of N. Y.
3. J. E. Malone, Chicago, Ill.
With Illinois Steel Co.
5. K. D. Marlatt, Oakwell, Ont.
The Marlatt & Armstrong Co.

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*Diploma with honours.

1908—*Continued.*

1. R. J. Marshall, B.A.Sc., Toronto, Ont.
Demonstrator in Applied Mechanics, University of Toronto.

5. G. L. Milligan, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. A. B. Mitchell, Cambridge, Mass.
Student in Architectecture, Harvard University.

4.*J. C. P. Molesworth (deceased).

3. E. D. Monk, B.A.Sc., Pittsfield, Mass.
Testing Department, General Electric Co.

3.*F. H. Moody, B.A.Sc., 49-55 Lafayette St., New York, N.Y.
Associate Editor of "Machinery."

3. J. H. Morice, B.A.Sc., 938 Albany, St., Schenectady, N.Y.

3. F. E. H. Mowbray, B.A.Sc., Hamilton, Ont.
Canadian Westinghouse Co.

3.*W. P. Murray, B.A.Sc., Montreal, Que.
Dominion Bridge Co.

3. W. deC. O'Grady, Winnipeg, Man.
Engineer, Gas Traction Co., Ltd.

1. H. J. Peckover, B.A.Sc., Toronto, Ont.
Fellow in Drawing, University of Toronto.

1.*M. Pequegnat, B.A.Sc., Toronto, Ont.
Demonstrator in Drawing, University of Toronto.

1. H. G. Phillips, Saskatoon, Sask.
Phillips & Phillips, Civil Engineers and Surveyors.

3. M. Pivnick, Toronto, Ont.
Student in Dentistry.

1.*E. M. Proctor, B.A.Sc., Toronto, Ont.
Draftsman, Canada Foundry Co.

3.*C. F. Publow, B.A.Sc., 305 Gladstone Ave., Toronto, Ont.

1. J. T. Ransom, B. A.Sc , Toronto, Ont.
Fellow in Surveying, University of Toronto.

1.*W. B. Redfern, B.A.Sc., Steelton, Ont.
Resident Engineer for Willis Chipman, C.E.

1. F. L. Richardson, B.A.Sc., Toronto, Ont.
With Miller, Cummings & Robertson.

3. H. A. Ricker, B.A.Sc., 101 Leeming St., Hamilton. Ont.

1. A. R. Robertson, B.A.Sc., Toronto, Ont.
Staff of City Engineer.

5. F. A. Robertson, Toronto, Ont.
Assistant Advertising & Business Manager, Farmers' Magazine.

1.*W. A. Robinson, Winnipeg, Man.

3. R. C. Robinson, 134 Edmonton St., Winnipeg, Ont.

5. L. J. Rogers, Toronto, Ont.
Demonstrator in Chemistry, University of Toronto.

2.*R. R. Rose, B.A.Sc., Copper Cliff, Ont.
With Canadian Copper Co.

3. D. Ross, 387 Princess Ave., London Ont.

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*Diploma with honours.

1908—*Continued.*

1. A. O. Secord, Brantford, Ont.

3. W. E. V. Shaw, B.A.Sc., Toronto, Ont.
Purchasing Engineer, Hydro-Electric Power Commission.

3. H. F. Shearer, B.A.Sc., E. Norwood, Ohio.
Testing Engineer, Bullock Electric Mfg. Co.

1. W. L. Stamford, B.A.Sc., Point du Bois, Man
Inspector on Concrete Work, Hydro-Electric Power Plant.

3. R. H. Starr, B.A.Sc., Toronto, Ont.
Toronto Hydro-Electric System, City Hall.

3. A. W. J. Stewart, Toronto, Ont.
Electrical Department, City Hall.

3. J. St. Lawrence, Erie, Pa.
Supt. of Engine Shops, Erie City Iron Works.

1. J. J. Stock, Toronto, Ont

1. H. B. Stuart, B.A.Sc , Hamilton, Ont.
Draftsman, Hamilton Bridge Works Co.

2. J. L. G. Stuart, B.A.Sc., Toronto, Ont.
Railway & Special Works Department, City Hall.

3. A. D. Sword, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

3. J. W. R. Taylor, B.A.Sc., Hamilton, Ont.
With Canadian Westinghouse Co.

1.*W. E. Taylor, B.A.Sc., Toronto, Ont.
Fellow in Drawing, University of Toronto.

3. V. C. Thomas, B.A.Sc., Toronto, Ont.
Demonstrator in Hydraulics, University of Toronto.

1. J. H. Thornley, B.A.Sc., 943 Dundas St., London. Ont.

1. C. G. Toms, B.A.Sc., 60 Spencer Ave., Toronto, Ont.

1. H. W. Tye, Winnipeg, Man.
Construction Dept., C.P.R.

3. C. P. Van Norman, Toronto, Ont.
Post-graduare Course in Engineering, University of Toronto.

1. T. L. Villeneuve, Chicoutimi, Que.
Assistant Engineer, Dept., of Public Works.

1. J. A. Walker, B.A.Sc., Nelson, B.C.
With A. L. McCulloch, C.E., B.C.L.S.

3.*B. W. Waugh, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3. R. M. Wedlake, B.A.Sc., Brantford, Ont.
With Cockshutt Plow Co., Ltd.

3. R. P. Weir, Toronto, Ont.
With C. H. Mitchell, Consulting Engineer.

1. A. M. West, B.A.Sc., Vancouver, B.C.
C.N.R. Office.

1. W. R. White, Drayton, Ont.

3. W. J. White, B.A.Sc., Boston, Mass.
Supt., on Construction, General Electric Co.

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*Diploma with honours.

1908—*Continued.*

3.*F. D. Wilson, Toronto, Ont.
Draftsman, McGregor & McIntyre, Ltd.
1. J. M. Wilson, Moose Jaw, Sask.
City Engineer.
1. D. O. Wing, Prince Rupert, B.C.
With G.T.P. Co.
3*R. Young, Lake Burnstzean, Burrard Inlet., B.C.

1909.

3. E. G. Arens, Niagara Falls, Ont.
Draftsman with H. D. Symmes, Contractor.
3. H. V. Armstrong, Dunnville, Ont.
Engineering Staff of Willis Chipman, C.E.
2.*E. T. Austin, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. W. H. Barry, B.A.Sc., Niagara Falls, Ont.
3. R. D. S. Beckstedt, B.A.Sc., Wilkinsburg, Pa.
3. R. E. Beith, Cochrane, Ont.
With Transcontinental Ry.
1.*G. A. Bennett, B.A.Sc., Box 1928, Calgary, Alta.
Domimion Land Surveyor, Dept. of the Interior.
3. E. R. Birchard, B.A.Sc., Barrie, Ont.
Canada Producer & Gas Engine Co.
3. W. D. Black, B.A.Sc., Montreal, Que.
Supt., Otis-Fensom Elevator Co., Ltd.
3.*D. C. Blizard, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1.*W. J. Boulton, Wallaceburg, Ont.
3. G. H. Bowen, B.A.Sc., Niagara Falls, Ont.
Engineer on Construction, Queen Victoria Park.
3. C. E. Brown, B.A.Sc., Hamilton, Ont.
Canadian Westinghouse Co.
1. E. W. Browne, B.A.Sc., 247 Cannon St. E., Hamilton, Ont.
1. J. A. Buchanan, Comber, Ont.
3. J. E. Burns, B.A.Sc., 231 Seaton St., Toronto, Ont.
1. M. G. Cameron, B.A.Sc., Peterboro', Ont.
3.*R. A. Campbell, Alliston, Ont.
1. V. S. Chesnut, Mount Lebanon, B.C.
Canadian Northern Ontario Ry.
1.*C. G. Cline, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. J. G. Collinson, B.A.Sc., St. Thomas, Ont.
1. G. W. Coltham, B.A.Sc., Aurora, Ont.
3.*H. A. Cooch, B.A.Sc., Toronto, Ont.
Demonstrator in Electrical Engineering, University of Toronto.

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*Diploma with honours.

1909—*Continued.*

3. W. E. Corman, Stony Creek, Ont.
3. T. H. Crosby, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. R. H. Cunningham, Chicago, Ill.
With Bryan-Marsh Co.
1.* F. A. Dallyn, B.A.Sc 1488 King St. W., Toronto, Ont.
3. C. N. Danks, Sherbrooke, Que.
Draftsman, Canadian Rand Co., Ltd.
1. E. M. Dann, Ottawa, Ont.
Railway Lands Branch, Dept. of the Interior.
3. H. W. Davis, Kingston, Ont.
With A. Davis & Son, Ltd., Leather Manufacturers.
2.*A. I. Davis, B.A.Sc., 82 Kendal Ave., Toronto, Ont.
1. H. C. Davis Burlington, Ont.
1. I. H. Dawson, St. Catharines, Ont.
Draftsman.
3. W. H. Delahaye, B. A. Sc., Pembroke, Ont
3. W. P. Derham, B.A.Sc., Ottawa, Ont.
5.*W. A. Dodds, B.A,S.c., Syracuse, N.Y.
With Penman Littlehales Chemical Co.
1. R. H. Douglas, Edmonton, Alta.
Department of Public Works.
1. F. S. Falconer, B.A.Sc., Shelburne, Ont.
3. T. A. Fargey, B.A.Sc., Newark, N. J.
With General Electric Co.
1. J. B. Ferguson, Chicago, Ill.
3. A. T. Fergusson, B.A.Sc., Toronto, Ont.
3. T. E. Freeman, B.A.Sc., Peterboro', Ont.
Canadian General Electric Co.
3. E. R. Frost, B.A.Sc., Toronto, Ont.
With Smith, Keery & Chace.
1. A. E. Glover, Toronto, Ont.
Post-graduate Coures in Engineering, University of Toronto.
5. A. E. Gooderham, Toronto, Ont.
1. D. A. Graham, B.A.Sc., Ivan, Ont.
2. R. R. Grant, 106 Warren Rd., Toronto, Ont.
1. J. E. Gray, Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. G. E. D. Greene, B.A.Sc., Toronto, Ont.
1. W. H. Greene, 26 South Drive, Toronto, Ont.
1. W. W. Gunn, B.A.Sc., Montreal, Que.
With Dominion Bridge Co.
3. C. J. Harper, Pittsfield, Mass.
1. D. W. Harvey, B.S.Ac., London, Ont.
1. C. O. Hay, 114 Liberty St., New York, N.Y
Supt. on Construction, Muralt & Co.

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*Diploma with honours.

1909—*Continued.*

3.*J. Hemphill, *Canton Electric Power Co.*	Canton, Ohio.
1.*G. Hogarth, *Engineer's Office, Dept. of Public Works of Ontario.*	Toronto, Ont.
3. A. E. Holmes, B.A.Sc., *Canadian Westinghouse Co.*	Hamilton, Ont.
3. C. R. Holmes, *Post-graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. G. C. Hoshal, B.A.Sc.,	Toronto, Ont.
3. C. Hughes, B.A.Sc.,	Toronto, Ont.
1. A. E. Hunter, B.A.Sc.,	Toronto, Ont.
3.*H. Irwin, B.A.Sc., *Secretary, Engineering Society, University of Toronto.*	Toronto, Ont.
3. J. Isbister, B.A.Sc.,	Wingham, Ont.
3. F. P. Jackes, B.A.Sc., *With Canadian Westinghouse Co.*	Toronto, Ont.
1.*J. E. Jackson,	Oxford Centre, Ont.
1. E. W. James, B.A.Sc.,	Toronto, Ont.
1.*C. C. Johnson, B.A.Sc., *City Hall.*	Toronto, Ont.
1. C. E. Johnston. *Post-graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. W. J. Johnston,	Porcupine, Ont.
1.*A. H. E. Keffer, *With T. & N.O. Ry.*	North Bay, Ont.
3. J. B. O. Kemp, B.A.Sc., *Fellow in Drawing, University of Toronto.*	Toronto, Ont.
3. W. R. Key, B.A.Sc., *Mechanical Draftsman.*	Toronto, Ont.
5. H. N. Klotz, B.A.Sc., *Chemist, Gutta Percha & Rubber Co.*	Toronto, Ont.
3. A. W. Lamont, B.A.Sc., *Sales Engineer, Canadian Westinghouse Co., Ltd.*	Winnipeg, Man.
3.*C. B. Langmuir, B.A.Sc., *Sales Dept., Factory Products, Ltd.*	Toronto, Ont
3. A. E. Lennox, B.A.Sc., *National Electric Lamp Association.*	Cleveland, Ohio.
1.*R. W. E. Loucks, *Asst. to A. Fawcett, D.L.S.*	Delisle, Sask.
1. N. C. A. Lloyd,	
3. E. D. MacFarlane, B.A.Sc.,	Cleveland, Ohio.
1. J. G. Mackinnon, *Optical Dept., T. Eaton Co.*	Toronto, Ont.
1. W. A. MacLachlan	Guelph, Ont.
3. B. A. Maclean, B.A.Sc.,	Hamilton, Ont.
1. N. W. Macpherson, B.A.Sc.,	St. Thomas, Ont.

*Diploma with honours.

1909—*Continued.*

3. D. D. McALPINE, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. A. S. McARTHUR, B.A.Sc., Toronto, Ont.
3. C. R. McCOLLUM, B.A.Sc., Toronto, Ont.
With Canada Cycle & Motor Co.
3.*A. S. McCORDICK, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. P. J. McCUAIG, B.A.Sc., Milwaukee, Wis.
1. F. H. McKECHNIE, Cochrane, Ont.
Resident Engineer, Trans. Ry.
3. W. G. McINTOSH,.
3. G. McLEOD, Waupaca, Wis.
Electrician, Electric Light & Ry. Co.
1. V. McMILLAN, B.A.Sc., Toronto, Ont.
3. N. H. MANNING, B.A.Sc., Toronto, Ont.
Demonstrator in Mechanical Engineering. University of Toronto.
1.*A. B. MANSON, B.A.Sc., Stratford, Ont
City Engineer's Staff.
1.*E. S. MARTINDALE, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. O. W. MARTYN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2. C. A. MORRIS, B.A.Sc., Toronto, Ont.
3. G. MORTON, B.A.Sc., Calgary, Alta.
Canadian Westinghouse Co.
1.*F. V. MUNRO, B.A.Sc., Toronto, Ont.
Fellow in Drawing, University of Toronto.
1. E. A. NEVILLE, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. J. NEWTON, B.A.Sc., Toronto, Ont.
City Engineer's Department.
3.*L. S. ODELL, Toronto, Ont.
Fellow in Drawing, University of Toronto.
3. V. J. O'DONNELL, Toronto, Ont.
3. J. J. O'HEARN, Peterboro', Ont.
Canadian General Electric Co.
1. A. W. PAE, Calgary, Alta.
District Hydrographer.
1.*A. M. PETRY, B.A.Sc., Toronto, Ont.
Assistant Manager, " Chas. Potter."
1. R. B. PIGOTT, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2. G. M. PONTON, Blairmore, Alta.
With West Canadian Collieries Co.
3.*C. J. PORTER, B.A.Sc., Portland, Oregon.
Draftsman, Mount Hood Ry. & Power Co.
3. A. I. PROCTOR, Hamilton, Ont.

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*Diploma with honours.

1909—*Continued.*

1. J. QUAIL,	Toronto, Ont.
1. A. F. RAMSPERGER, *Draftsman, With Toronto Iron Works Ltd.*	Toronto, Ont.
1.*C. R. REDFERN, B.A.Sc., *Demonstrator in Applied Mechanics. University of Toronto.*	Toronto, Ont.
3.*L. T. RUTLEDGE, B.A.Sc., *Fellow in Drawing, University of Toronto.*	Toronto, Ont.
1. A. U. SANDERSON, B.A.Sc.,	Toronto, Ont.
3.*R. A. SARA, *Post-Graduate Course in Engineering, Univrsity of Toronto.*	Toronto, Ont.
3.*A. SCHLARBAUM, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3.*C. SCHWENGER, B.A.Sc., *Electrical Department, City Hall.*	Toronto, Ont.
1. C. A. SCOTT, *Roadway Department, City Hall.*	Toronto, Ont.
1. A. SEDGWICK, *Engineer, Dog Lake Storage Works.*	Kaministikuia, Ont.
1. B. H. SEGRE,	Winnipeg, Man.
1. F. V. SEIBERT, *Fellow in Surveying, University of Toronto.*	Toronto, Ont.
5. M. R. SHAW, *Chemist, Dow Chemical Co.*	Midland, Mich.
3. M. W. SPARLING, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3. J. J. SPENCE,	Toronto, Ont.
1. D. S. STAYNER, B.A.Sc., *Bridge Department, City Engineer's Office.*	Toronto, Ont.
1.*N. C. STEWART, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1.*P. H. STOCK, *Resident Engineer, N. St. C. & T. R. Ry.*	St. Catharines, Ont.
1. J. C. STREET, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3. S. STROUD, B.A.Sc., *Westinghouse Electric & Manufacturing Co.*	East Pittsburgh, Pa.
1. C. C. SUTHERLAND, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. R. G. SWAN, B.A.Sc.,	Toronto, Ont.
1. A. D. SWORD, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1.*H. W. TATE, B.A.Sc.,	Toronto, Ont.
3.*E. A. THOMPSON, *With Smith, Kerry & Chace.*	Toronto, Ont.
1. G. A TIPPER, B.A.Sc.,	Toronto, Ont.
3. A. G. TREES, B.A.Sc.,	Toronto, Ont.

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*Diploma with honours.

1909—*Continued.*

3. W. G. TURNBULL, B.A.Sc., *The Cutler Hammer Mfg. Co.*	Milwaukee, Wis.
1. J. E. UNDERWOOD,	Lakelet, Ont.
1. C. P. VANNORMAN, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. J. VANNOSTRAND, *Student.*	Toronto, Ont.
1. A. VATCHER, B.A.Sc., *With the Reid Newfoundland Co.*	Freshwater, Bay deVerde, Nfl.
1. C. M. WALKER, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. E. E. WEBB,	Orillia, Ont.
1. C. E. WEBB, B.A.Sc.,	Toronto, Ont.
3. F. C. WHITE, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3. A. R. WHITELAW, *With Smith, Kerry & Chace.*	Toronto, Ont.
1. R. G. WILKINSON,	Aberarder, Ont.
5.*J. A. McK. WILLIAMS, B.A.Sc.,	Toronto, Ont.
1.*O. T. G. WILLIAMSON, B.A.Sc.,	Guelph, Ont.
3. L. R. WILSON, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3. F. F. WILSON, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
2. S. A. WOOKEY, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.

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2. J. H. ADAMS, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3.*O. F. ADAMS, *Fellow in Electrical Engineering, University of Toronto.*	Toronto, Ont.
1.*W. G. AMSDEN, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. J. A. BAIRD, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1.*W. J. BAIRD.	
1. H. A. BARNETT, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1.*E. W. BERRY,	Seaforth, Ont.
1.*H. C. BINGHAM, *City Engineer's Department.*	Moose Jaw Sask.
2. D. G. BISSET, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. R. H. H. BLACKWELL,	Toronto, Ont.
1.*E. P. BOWMAN, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.

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*Diploma with honours.

1910—*Continued.*

2. A. F. BROCK, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. M. O. BROWNE, Toronto, Ont.
3. J. R. BURGESS, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. N. G. H. BURNHAM, Toronto, Ont.
3.*W. C. CALE, Glenwood Springs Colo.
With Central Colorado Power Co.
2.*A. D. CAMPBELL, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. W. M. CARLYLE, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. N. S. CAUDWELL, Toronto, Ont.
1.*D. C. CHISHOLM, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
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3. L. S. COCKBURN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. A. G. CODE, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. C. R. COLE, Woodstock, Ont.
1. G. A. COLQUHOUN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
4.*J. H. CRAIG, Toronto, Ont.
Fellow in Drawing, University of Toronto.
3.*C. D. DEAN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. R. L. DOBBIN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3.*W. P. DOBSON, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3.*J. M. DUNCAN, Toronto, Ont.
2. V. H. EMERY, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. W. J. EVANS, Jermyn, Ont.
3. H. W. FAIRLIE, Toronto, Ont.
Tungsiolier Co., of Canada.
3.*C. R. FERGUSON, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. J. W. FERGUSON, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
4.*J. B. K. FISKEN, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. A. W. FLETCHER, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1.*J. A. FLETCHER, Fisher River, Man.
Assistant to E. W. Robinson, D.L.S.

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*Diploma with honours.

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3. F. T. Fletcher, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
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3. R. C. Follett,
2. J. M. Foreman, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. W. J. Foster,
3.*W. C. Foulds, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. A. Fraser, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2. J. Fredin, London, Ont.
1. M. M. Gibson, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. V. A. E. Goad, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. V. S. Goodeve, Toronto, Ont
2. W. A. Gordon, Sundridge, Ont.
3. V. F. Gourlay, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2. R. L. Greene. Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
5. J. H. Harris, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1.*N. J. Harvie, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. J. G. Helliwell, Toronto, Ont.
1. J. F. Henderson, Toronto, Ont.
3. F. G. Hickling, Wilkinsburg, Pa.
2.*P. E. Hopkins, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3.*W. J. Irwin, East Pittsburg, Pa.
Apprenticeship Course, Westinghouse Machine Co.
2. F. L. James, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. H. C. Johnston, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. R. H. Johnson, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. J. C. Keith, Toronto, Omt.
Post-Graduate Course in Engineering, University of Toronto.
2.*J. T. King, Toronto, Ont.
Fellow in Mining Engineering, University of Toronto.
3. G. A. Kingstone, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2. G. L. Kirwin, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

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*Diploma with honours.

1910—*Continued.*

5. P. T. Kirwin, Toronto, Ont.
Fellow in Chemistry, University of Toronto.

1. S. Knight, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

3. E. R. Lawler, Toronto, Ont.

3.*C. B. Leaver, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

3. R. G. Lee, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1. J. C. Longstaff, Toronto, Ont.

3. J. B. MacDonald, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

2.*A. D. Macdonald,

1. J. A. MacDonald, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1. G. A. MacDonald, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1.*A. E. MacGregor, Wilkeson, Wash.
Analyst & Draftsman, Wilkeson Coal & Coke Co.

1. E. G. MacKay, Hamilton, Ont.

1.*G. G. MacLennan, Prince Albert ,Sask.
Assistant to A. St. Cyr, D.L.S.

1. D. D. MacLeod, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

3. H. G. MacMurchy, Toronto, Ont.
Post-Graduate Course in Ebgineering, University of Toronto.

3.*H. J. MacTavish, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

4. T. C. McBride, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1. S. G. McDougall, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1.*T. A. McElhanney, Kincardine, Ont.

1.*P. J. McGarry, Merriton, Ont.

3.*L. R. McKim, Wyecombe, Ont.

1.*J. McNiven, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

3. J. I. McSloy, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

2. A. W. R. Maisonville, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

1.*N. Marr, Cochrane, Ont.
Engineering Staff, Transcontinental Ry.

1.*W. H. Martin, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

2. A. C. Matthews, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.

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1910—*Continued.*

3.*H. O. Merriman, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1.*D. J. Miller, Orillia, Ont.
1. F. S. Milligan, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. P. E. Mills, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. J. P. Morgan, Newmarket, Ont.
1. A. H. Munro, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. J. C. Nash, Hamilton, Ont.
Draftsman, Canadian Westinghouse Co.
1.*V. A. Newhall, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2.*W. E. Newton, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. F. T. Nichol, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1. C. M. O'Neil, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. C. E. Palmer, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. G. C. Parker, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. K. K. Pearce, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
3. C. H. Phillips, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
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1. W. S. Ramsay, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto
3. B. J. Redfern, Toronto, Ont.
1. H. C. Ritchie, Calgary, Alta.
1. O. W. Ross, Lachine, P.Q.
With Dominion Bridge Co.
1. W. F. B. Rubidge, Dixie, Ont.
3. W. C. Shaw, Toronto, Ont.
1 *W. C. Smith, Two Harbors, Minn.
With D. & I. R.R. Co.
5. G. E. Smith, Toronto, Ont.
2. R. J. Spry, Greenwood, B.C.
Metallurgist, The B. C. Copper Co.
2. A. L. Steele, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
2.*H. M. Steven, Toronto, Ont.
Post-Graduate Course in Engineering, University of Toronto.
1.*L. I. Stone, Toronto, Ont.

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3. A. L. Sutherland, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3. E. A. Ternan, *Engineering Dept., Canadian General Electric Co.*	Toronto, Ont.
5.*W. H. Thom,	Watford, Ont.
3. H. B. Thompson,	Wellington, Ont.
3. R. M. A. Thompson, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
2.*C. G. Titus, *Manager, The Bartlett Mines.*	Gowganda, Ont.
3. K. M. vanAllen, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. L. T. Venney, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. N. Wagner, *Bridge Dept., Canada Foundry Co.*	Toronto, Ont.
1. R. M. Walker,	
2. T. Walton, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. G. A. Warrington, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
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4. W. S. Wickens, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3.*G. K. Williams, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1.*W. H. Wilson, *Fellow in Physics, University of Toronto.*	Toronto, Ont.
1. G. R. Workman, *With the Laurentide Paper Co., Ltd.*	Grand Mere, Que.
3. L. A. Wright, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
3.*A. W. Youell, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.
1. W. S. Young, *Post-Graduate Course in Engineering, University of Toronto.*	Toronto, Ont.

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PRELIMINARY PROBLEMS IN THE DESIGN OF MANUFACTURING BUILDINGS.*

E. H. DARLING, '98.

Assistant Engineer, Hamilton Bridge Works Co., Hamilton.

The actual design of a manufacturing building, as a structure which is to be built of certain materials, to carry given loads, does not, as a rule, present any engineering difficulties which cannot be satisfactorily solved by the usual methods given in books that treat on this subject. It resolves itself simply into the problem of ascertaining, as nearly as possible, the stresses which the loads produce, and of proportioning the materials to take care of these stresses. The *Preliminary Problems* however, which fix the nature of the building, its size, shape, arrangement, the materials to be used, and the loads to be provided for, all form an immensely broader subject, extending beyond the bounds usually set for the engineer, and touching the very heart of the world of Business and Manufacturing.

These preliminary problems bear the same relation to the detail design that the work of the locating engineer on a new railroad bears to the work of the man who stakes out the line, only in the case of manufacturing buildings they are more complexed. In the following discussion, the writer will endeavor to show how exceedingly complex the designing of a manufacturers' building may be, and the relation of the engineer to this only partially developed field of work. Older members of the Engineering Society will probably find little in it of interest or profit, for it is written for the purpose of stimulating the minds of the younger members by suggesting lines of thought which will tend to broaden their ideas of the profession they have chosen.

Before one can appreciate the complexity of the problems which the design of manufacturing buildings presents it is necessary that he have a thorough knowledge of building materials and the special use for which they are adapted.

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* Read before the University of Toronto Engineering Society, Nov. 1st., 1911

It would take many books to exhaust this subject, and we can here only briefly describe three of the common types of Construction, namely:—

1. Slow burning or mill construction.
2. Fire proof construction.
3. Steel frame construction or mill buildings.

1. Slow Burning Construction.

Slow burning or mill construction is simply a special class of timber work. Such a building will have heavy brick walls with the interior columns, beams and floors of massive timbers so disposed as to present the least possible opportunity for the spread of fire. The columns are made of single timbers, usually square, capped with a corbel or short beam which forms a seat for the column of the next floor above, and supports the cross beams which carry the floor. This corbel may be replaced by a steel or cast iron cap which is more reliable when the loads are great. The cross-beams are also heavy single timbers and on these are laid 2in. by 4in., or 2in. by 6in. pieces set on edge and spiked together so as to form a floor 4in. or 6in. thick, as the case may be. A hardwood wearing floor 1in. thick is usually laid on this. Note the absence of all joist and any thin projecting woodwork which might easily catch fire. In case a fire should start, the thick floors would tend to confine it to one story and the heavy beams and columns would burn slowly, thus giving the fire department a chance to put it out before it destroyed the whole building. This construction is only effective, however, when used intelligently, for unless all the many rules for preventing the spread of fire are carefully observed, the result may be disastrous.

The roof of such a building may be constructed like the floor, or, if the span between the rafters is not too great, matched sheeting may be used. This is covered with a felt and gravel roofing material or some one of a score of special roofings which will resist the attack of fire.

The cost of long timber of large cross section practically limits the length of beams to somewhere between twelve and sixteen feet. This means that in a wide building there will have to be many columns which take up room and interfere with the arrangement of machinery.

2. Fire-proof Construction.

While there might be a difference of opinion as to how far it is expedient to go in making a particular manufacturing building fire-proof, it is well understood that, if a building is to stand all the vicissitudes of a conflagration, it must be made entirely of brick, concrete, terra-cotta, and steel, the steel to be well protected from the direct heat of the fire.

It is in office buildings, hotels and tenement houses that fire-proofing principles have been most extensively applied, and the manufacturer who requires a building of somewhat similar form will use similar methods of construction, adapting them to his special needs. Re-inforced concrete may be used entirely for floors, beams and columns, or steel may be used for the beams and columns to form a framework to carry the floors. In this case the steel must be covered with at least 1½in. to 2in. concrete.

Terra-cotta is being introduced for use in certain classes of manufacturing buildings, but being more or less brittle and not suitable to withstand vibration and shocks, its use is limited. Its most extensive use is in the form of tile for roofs, where its lightness is an advantage.

3. Steel Frame Buildings.

This class of construction is used for rolling-mills, machine shops, foundries, etc., which are usually classified under the head of Mill Buildings. Its distinctive feature is the steel skeleton which forms a frame to support the roof and side covering. This covering is usually corrugated iron, galvanized and sometimes painted also. When so constructed the building is entirely metal, even the window sash may be made of steel. The result is that it can stand an immense amount of rough usage and, unless filled with inflammable material, is not easily injured by fire, nor is it effected by the elements provided it is regularly painted and properly cared for.

But in a building of this class its function as a protection from the weather is really secondary, its main duty being to sustain cranes, hoists and other machinery. In fact, the structure is a huge machine itself. In its design the same engineering principles are applied which are used in the building of steel bridges. Every possible stress is estimated and provided for. Often the analysis of these stresses is made extremely complicated by special combinations of traveling cranes, bins, machinery and wind pressures, but all must be taken care of if the building is to be rigid and safe.

Each of the above three types of Construction has its own special advantages and they are often combined in various ways to obtain a desired result. The slow-burning construction has the advantage of being cheap in first cost. Until recently it had a further advantage of time in rapid erection, but it is now so difficult to obtain first class lumber and the cost is such that these advantages are lost. The commercial size and length of timbers obtainable also limits the span of beams and the spacing of the columns, as explained above. However, for factory buildings, such as woolen and cotton mills, etc., where the machinery is small and light, this feature is not necessarily objectionable. But the one which weighs heaviest against it is its inflammability. That means, for one thing, high insurance rates and the ever present danger of fire.

The first natural variation made in slow burning construction, is the substitution of steel for beams and columns. This permits longer spans for the beams and heavier loads on both beams and columns. Steel columns are often put in the outside walls as well. The steel work is then self-supporting and may be erected complete independently of other trades. As these columns relieve the walls of all beam loads, and also re-inforce it, the walls may be made much lighter than would otherwise be permissible. As a fire risk, however, this combination is considered inferior to the slow burning construction. Steel becomes soft at a red heat and is entirely unable to resist stresses. If, when thus heated, a stream of water is directed on it, it warps and twists. While an ordinary fire will not actually destroy the metal, the physical state of the material may be so altered as to be entirely unreliable. Consequently its salvage value is only what it will bring as "scrap."

In buildings of three or four stories, round cast iron columns are sometimes substituted for the rolled steel. If neatly cast, they present a better appearance than the built-up steel column, but unless designed by one accustomed to working with cast iron and unless they are most rigidly inspected, there is always a very great uncertainty as to their strength. Apart from this unsatisfactory feature, cast iron has the advantage over steel in being better able to resist heat. They will usually cost more than the steel column.

If, in buildings where steel is used, it is protected by about two inches of concrete, practically all the risk of damage from fire is eliminated. This is rarely if ever done if the floors are of wood, for if the fire-proofing is carried to this extent, is only means one step more to make the building entirely fire-proof. Wood floors, however, have this advantage in addition to being cheaper. It is much easier to cut openings or bore holes in them than it is in concrete, and that is an item worth considering where there is likely to be much of this work to do.

As stated above, buildings which are to be fire-proof must be constructed entirely of re-inforced concrete, or steel covered with concrete or terra-cotta. Buildings of this type have come through conflagrations and earthquakes with credit. The one thing to remember in using re-inforced concrete is that there must be no slighting of the work whatever. To get a good job, it is sometimes a continual fight against ignorance and carelessness, and sometimes dishonesty. A mistake once made is very hard to remedy. A defect may easily escape notice until a catastrophe occurs. Many accidents have already been recorded and there have probably been many more that have never reached the ears of the public. There are large new buildings which stand finished, but vacant, and condemned.

That this blot against re-inforced concrete is not fair to this construction, is proved by the fact that many engineers, especially European engineers, get quite satisfactory results although they use much higher unit stresses than the average. The secret is that they take more time for the work, and give it more rigid supervision.

By using a steel frame work for a building, much of the uncertainty as to its safety may be done away with. There is also a saving of head room and floor space, as the steel beams and columns are smaller than those of re-inforced concrete. In a building of many stories a few inches to each story adds up to quite an item. The columns in the lower stories become so large that, as one writer has put it, the building resembles the Egyptian pyramids—most of the room is on the outside. Nor are engineers agreed as to how concrete sets when poured wet in large masses.

There are other objections to the use of re-inforced concrete for certain classes of manufacturer's buildings. Where it is necessary to make frequent changes, alterations and repairs and in fact in any structure that is not intended to be permanent for many years, it becomes very costly. When it has outlived its usefulness, it is expensive to remove and the materials have little or no value.

Referring to steel frame mill buildings, structural steel has other useful properties in addition to those referred to above. Such a building is not limited to any size, shape or form within reason. Any loads can be taken care of with certainty. The erection of the frame usually goes ahead very rapidly, forming a scaffold for other work. Steel must, however, be frequently painted if exposed to moisture or corrosive gases to prevent rust and coercion.

This brief description of the three classes of manufacturers buildings will give an idea of the principal materials at the disposal of the designer and the special properties of each. In addition to these, there are innumerable patented building supplies of all varieties and grades from which the designer may choose those best adapted to his needs or taste, and the amount of the money appropriated for the work. With all this data at his finger tips, he is in a position to consider the preliminary problems relating to the design of any particular plant. These problems may be discussed under three heads.

1. The problems of utility.
2. The problems of location.
3. The problems of finance.

But while the discussion may be thus separated, in an actual case, the problems are so interdependent that they must be weighed, one against the other, in order to attain the highest possible efficiency. Efficiency in this case means the greatest ultimate value for every dollar expended.

Some of these problems can be handled by means of mathematics, with precision. Some can be settled by the obtaining of definite data. The facts once known, the question is settled beyond discussion. Some conclusions are reached instinctively, or through natural habit without conscious thought. But by far the larger part is a matter of judgment and the more highly this faculty is developed in the designer, the greater his knowledge, the wider his experience, the more accurate will be the solution.

Problems of Utility.

The use to which the building is to be put, will of course, largely determine the general type of design. In many lines of manufacture the building is virtually a tool or machine and as such it should have the same careful attention of an expert as is given to any part of the equipment. Many a plant with the latest and most expensive machinery is handicapped for all time by the poor design of the building that contains it.

Plants for the manufacture of similar products will probably resemble each other but need not necessarily be alike, for different methods, different ideas or special conditions may mean an entirely different lay-out. Fortunately the designer is not usually called upon to design the process of manufacture but it is essential that he have a thorough understanding of the routine through which the materials have to pass.

The amount of floor space, head room, light, ventilation, etc., that each process will require must be decided upon. The question of light receives a great deal more attention these days than formerly, and the effect on the design is quite marked. The different rooms or buildings must be so arranged that the materials may pass from one to the next with the minimum amount of handling or transportation. Provision must be made for the receiving of raw materials and for the shipping of the finished product. Necessary store rooms must be provided at convenient locations. The power plant should be so located as to make the distribution of power convenient and economical. The same rule applies to the heating and lighting plants and water-works system, and all this must be done with an eye to the health, convenience and safety of the employes.

The method and order of erection must always be kept in mind. The cost of putting certain materials in place may be greatly increased unless the work can be done in a certain order, or at a particular time.

Problems of Location.

The actual location of a manufacturing building is usually determined by the owner from business consideration with which the designer has nothing to do, but the site once fixed, the effect on the design of the building or plant is far reaching.

For every line of manufacturing there is an ideal lay-out, but to realize it one would have to have an ideal site, ideal facilities for obtaining power, labor materials and transportation, an ideal climate, and an ideal balance in the bank. Since such conditions are seldom if ever obtainable, it becomes the designer's aim to adapt his design to the special conditions and circumstances, and make the best use of what he has.

The nature of the climate where the building is to be erected must be taken into consideration. The extremes of heat and cold, the violence of storms, the possibility of cyclones and earthquakes, the maximum snow fall the roof will have to sustain, the depth of the first line for foundations, etc., are some of the questions that depend on the climate. If the plant is to be operated throughout the winter in a northern locality, the problem of heating becomes an important item. As a rule it is poor economy to put up a cold building and then install an expensive heating system to keep it warm. Apart from the mistakes made in this particular, nearly all the other questions will be taken care of by following local customs which have been found to give the most satisfactory results after long years of trial.

The locality in which the building site is situated also has a very important bearing in the design. The very nature of the building will depend upon the facilities for obtaining building materials and their cost. The conveniences for transportation and handling heavy girdles, etc., must often be considered. The designer must not only have a knowledge of the cost of brick, lumber, cement, stone, steel, terra-cotta, etc., at the place where they are produced, but must know the nearest source of his supply, the transportation charges, duty, etc., and the cost of labor required for placing the materials in the building. These latter considerations often prohibit the use of what would otherwise be economical and desirable construction.

Government restrictions and regulations for the health and safety of the employees and the protection of the public must be carefully observed. If the site is in a large city, the building laws will probably place further restriction upon the designer and give him something to puzzle over in his spare moments. In addition to this, there are usually many special by-laws relating to smoke, noise or other nuisances. In order to obtain reasonable insurance rates the rules of the Fire Underwriters must be carefully followed. Labor conditions must be studied, not only in their relation to the cost of the work, but there are places where the Unions can dictate what the nature of the building is to be.

The size, shape and position of the lot will practically determine the proportions and arrangement of building or buildings. In some cases the position of railway switches and the like control the general lay-out. The proximity of high buildings may make impossible the natural method of lighting and change the orientation.

The probability of future extension must be taken into consideration from the start and a general scheme sketched up for as far ahead as possible. A good plan is to build the plant in units so that the addition of a unit to each department will maintain the proper proportions of the whole plant. The installation of one machine in one department may require the addition of a whole wing, to the building, to take care of the corresponding increase in another department.

In this case, provision should be made for as many wings in proportion to the space provided for such machines. However, it is not always possible to apply this system. For example, in a plant where there are to be many electric motors (and the number is likely to increase), it would show great lack of foresight if the transmission system were so designed that it were necessary to re-wire the plant and put in larger distribution mains every time another motor was added to the equipment. Here is an instance where it would be true economy to anticipate the greatest capacity that would ever likely be required and provide for it at the start. Now the building itself is usually a construction to which this rule applies. Not only should a reasonable amount of room be provided for future needs, but it is even more important that the probability of any increase in floor loads or the capacity of cranes, etc., be taken into account, at the start. It is usually very unsatisfactory, and always expensive, to try and strengthen a building for loads greater than originally planned for, even though the type of construction will permit it. No one who has not had to face such a problem and be responsible for the results, can appreciate what it means, besides, it is exceedingly aggravating to the owner to find a scheme of extension blocked or crippled just through the lack of a little foresight in making the original lay-out.

The Problems of Finance.

The questions of finance which the designer has to consider usually have nothing to do with the securing of the money necessary to carry out the work. But the problem which he does have to keep in mind always is how to get the utmost efficiency from every dollar invested. This means more than merely saving money in the construction. "Savings never pay dividends." It means even more than getting good value for the money spent, for every dollar invested is just one more on which must be paid interest, taxes, etc., if the enterprise is to be a success. If instead of putting the dollar into unnecessary expensive construction or some inappropriate ornamentation, it is so used that it will save something in the cost of maintaining or operating the plant, this means increase in profits. The dollar so invested is helping to earn dividends and is not dead capital.

Thus all the financial problems to be considered here center around the principle of the ultimate value. Will it pay in the long run? But until an infallible rule can be discovered to answer this question, it will be necessary after using every device of mathematics and human wits to still trust to Providence for the results.

The success or failure of an investment depends on the rate of interest received from it and time it has to run. In the case of a building these terms mean the amount of service got out of it, its life or period of usefulness, and its final or "scrap" value. Just what constitutes economical construction for a particular building will depend upon the values given to these conditions.

As an illustration of extreme conditions, take the temporary grand-stand for a football match, and a ten story office building. For the former, which is to be used for a few hours only, the very cheapest type of construction is economical, while for the latter, whose period of usefulness will be fifty years or more, only the most permanent construction in spite of the greater cost, will pay.

Where the answer to this question with reference to some particular building is not so obvious, it is necessary to assume a certain number of years for the period of usefulness and fix on a sum which will fairly represent its value at the end of that period. From these figures it is possible to determine the per cent. which the value of the building decreases annually. For example, if the original cost of the building is $10,000 and it is estimated that at the end of twenty years its value will be about $3585, it can be shown that the annual decrease in the value is nearly 5%. This decrease is called "depreciation," and if the books of the owner are kept correctly, it will be taken care of in one of three different ways.

1. The value of the building as an asset will be decreased 5% every year. This is an approximate method and is only correct for the twentieth year.

2. A sufficient sum of money will be put aside each year and invested as a sinking fund so that at the end of twenty years it will amount to the total depreciation, in the above case, $6,415. The amount of the sinking fund at any time gives the depreciation of the building to date.

3. A certain sum will be spent annually in repairs so that at the end of the period the building will still be worth its original cost, $10,000.

Assuming that it is possible to get 5% per annum interest on money, the amount necessary to deposit in the sinking fund every year would be $194 (all problems of this nature are solved by the regular rules for annuities—a very interesting and profitable study for anyone having to do with long time investments).

This same amount, $194, represents the average sum which will have to be spent in repair to keep the building at a constant value by the third method. If to this we add the interest on the investment, 5% on $10,000=$500, we have $694, which is the actual amount the owner is paying each year for the building apart from such charges as taxes, insurance, etc.

Suppose a cheaper construction were used, so as to save $2,000 in the cost of the building, but that as a consequence the depreciation amounted to 10% per annum instead of 5%. Then the value of the building at the end of 20 years would be $973. The sinking fund would be $212.44, and the annual cost of the building, 5% on $8,000=$400. $400 plus 212 equals $612. This means an annual saving of $82 by using the cheaper construction which in 20 years would amount to $2,712—the ultimate saving to the owner, not counting the $2,000 saved in first cost.

In the above example the building has been considered simply as an investment, but a far more important consideration in a manufacturing building is its relation to the process of manufacture. Methods are constantly changing, requiring corresponding changes in the building long before it is worn out. In this sense again a manufacturers' building is like a machine—its period of usefulness is not always measured by its durability. Some little invention or change in process sends it to the scrap-heap. It may be just as good as new but it is worthless.

This relationship is so important in some lines of manufacturing that the method of considering the building as an investment as above is not worth bothering about except for purposes of bookkeeping. The only question asked is, will it reduce the cost of manufacturing sufficiently to pay for itself in a reasonable time?

Now the financial problems of manufacturing usually involve amounts of much greater magnitude than have to be considered in the building or plant. It is quite possible that $100,000 worth of goods could be turned out annually in a $10,000 building. Hence the great importance of the relation of the building to process of manufacture. In this case if 1% could be saved in the cost of the goods produced by increasing the cost of the building 10% it would pay for itself in one year.

If in a plant employing 100 men it were possible by cutting a door in a wall, by changing the location of a machine, by taking out an obstructing column or by some other device, to save 6-10 of a second of each man's time per minute or 6 minutes a day, it would mean that 99 men could then do the work which formerly required 100. If the average rate of wages were 20 cents per hour, it would save $600 a year. It can be shown that if the owner were to borrow $2,600 at 5% to make this alteration, it would pay for itself in 5 years.

But it may be that through faulty design in the first place, it is not possible to make this change, and as a result of this, the owner is losing $600 a year which in 20 years would amount to $19,846.

Many a manufacturer is losing this $19,846 and much more through carelessness in the design of his plant.

It may be noted here that saving in time in manufacturing is a double saving. Not only is there a saving in workmen's wages, but the capacity of the plant is increased as more work can be turned out in a given period. The profit on this extra work must be credited to the change which makes it possible. In addition to this, time in delivery is often a very important factor in securing a contract, and in such cases higher prices may be obtained.

The above discussion is an illustration of what is called Efficiency Engineering or Scientific Management as applied to buildings, a subject that is attracting a great deal of attention just at present. So fine are some engineers' figuring that it has been suggested that even the time which the manager of a concern spends in looking after and ordering repairs to a building be capitalized and added to the ultimate cost.

Usually, however, more weighty reasons make it unnecessary to go to such refinement. In any new venture, which has a struggle before it with a possibility of failure, the first cost must be kept down to the lowest possible figure even at the sacrifice of efficiency, and questions of future growth, may, within reason, be left to take care of themselves. While it is true many a manager to-day bewails his lack of foresight in not preparing for the rapid growth of his business, still it is better that conditions are as they are than that his business had been wrecked at the start by an overload of debt.

This brief statement of the preliminary problems in the design of manufacturers' buildings should make clear at least one fact, and that is that the final plan must be a compromise—a compromise between the "possible" and the "expedient," between the "ideal" and the "practicable." In the completed building there may be many things that at first glance look like blunders, but a deeper investigation will show a carefully thought out purpose.

A good definition of an ideal building is given by Mr. Charles Day in his book "Industrial Plants." He says: It must so conform with all the industrial requirements that "the work of manufacturing may go forward with practically as much freedom as though the building did not exist at all. That is, the workers, whether employed at individual machines or engaged in moving material from point to point, should, to all intents and purposes, be unconscious of the existence of the housing structure." The building that will answer all requirements thus efficiently for the least cost—the period of use being considered—will be the best solution of the problem.

This discussion should also bring out the fact that the design of manufacturing buildings is more of an engineering than an architectural work. It will have been noticed that throughout this paper the name "designer" has been used and not "architect" or "engineer." The reason is that neither of these names, used in their usual sense, gives a correct idea of this branch of the profession. A new term has come into use and we know have the "Industrial Engineer."

The average architect is not only entirely incompetent to handle these problems but all his training quite unfits him for this class of work. The ordinary rules of architecture are too narrow to be applied to what is virtually a machine. Besides, in a large number of cases the questions of architecture never enter at all. There are many examples of handsome but inefficient manufacturing buildings. On the other hand there is a great deal of justice in the charge that works designed by the Engineer are unnecessarily hideous, and the Industrial Engineer cannot consider himself properly qualified if he has not a knowledge of the ordinary rules of architecture and aesthetics as applied to buildings.

But, as shown above, the work of the Industrial Engineer requires more than a knowledge of Architecture and Structural Engineering. He must have at least a general knowledge of Applied Science in all its branches in order to be able to grasp the salient features of any part of the manufacturers' installation, or his process of manufacture. It is not to be expected that he should be able to advise his client in his own business of manufacturing but he will often find that his clients' ideas of what he wants are limited by his lack of knowledge as to what is practicable. Here the engineer can be of assistance. It must be admitted, however, that more often the engineer will have reason to feel extremely flattered by his clients' faith in his ability to accomplish the impossible.

In addition to his professional training, the industrial engineer must have a broad mind, free from narrow prejudices, to be able to appreciate the good points in special materials and constructions. He must have sound judgment and a fair talent for prophecy to build for the future. He must be a wide-awake, up-to-date business man with more than enough ability to handle the details of his own work for the financial problems referred to above require a business acumen not usually expected of an engineer.

After all the preliminary problems in connection with some particular building have been threshed out, the actual work on the design and construction can begin. If the engineer has complete charge of the work, then follows in natural order the making of the general plans and specifications, the calling for tenders, selecting reliable contractors and awarding the contracts, the laying out the lines of the work, the fixing of levels, the checking and approving detail drawings, the inspection of materials and work, the ordering and installing of and putting in operation the equipment and the thousand and one details which have to be attended to in order that the work may be done in an orderly, expeditious and systematic way and be brought to a satisfactory and successful conclusion.

But these problems have to do with the actual design and construction and are beyond the scope of this paper.

MR. LEONARD'S APPOINTMENT.

R. W. Leonard, C.E., has recently been appointed successor to Hon. S. N. Parent, as chairman of the National Transcontinental Railway Commission. Mr. Leonard needs no introduction to engineers, and more especially to "School" men. "The Scope of Engineering in Canada" was the subject of an address delivered by him to the Engineering Society and published in the November, 1910, issue of this journal. He is also known as an active member of the Board of Governors of the University of Toronto. More particularly as an engineer after his own definition of the term has he formed his acquaintance, and his recent appointment to the Commission denotes a lofty recognition of his ability and qualifications as a member of the profession.

Among the recent staff appointments are the following:—Mr. P. Gillespie, Associate Professor of Applied Mechanics; Mr. H. W. Price, Associate Professor of Electrical Engineering; Mr. G. R. Anderson, Associate Professor of Physics; Messrs. L. M. Arkley and L. B. Taylor, lecturers in Mechanical Engineering. Newly appointed demonstrators are:—in Electrical Engineering, T. H. Crosby, '09; Mechanical Engineering, A. W. Youell, '10, and F. S. Milligan, '10; Architecture, C. R. Redfern, '09, and L. T. Rutledge, '09.

CENTRALIZATION OF HEAT, LIGHT AND POWER FOR THE UNIVERSITY OF TORONTO.

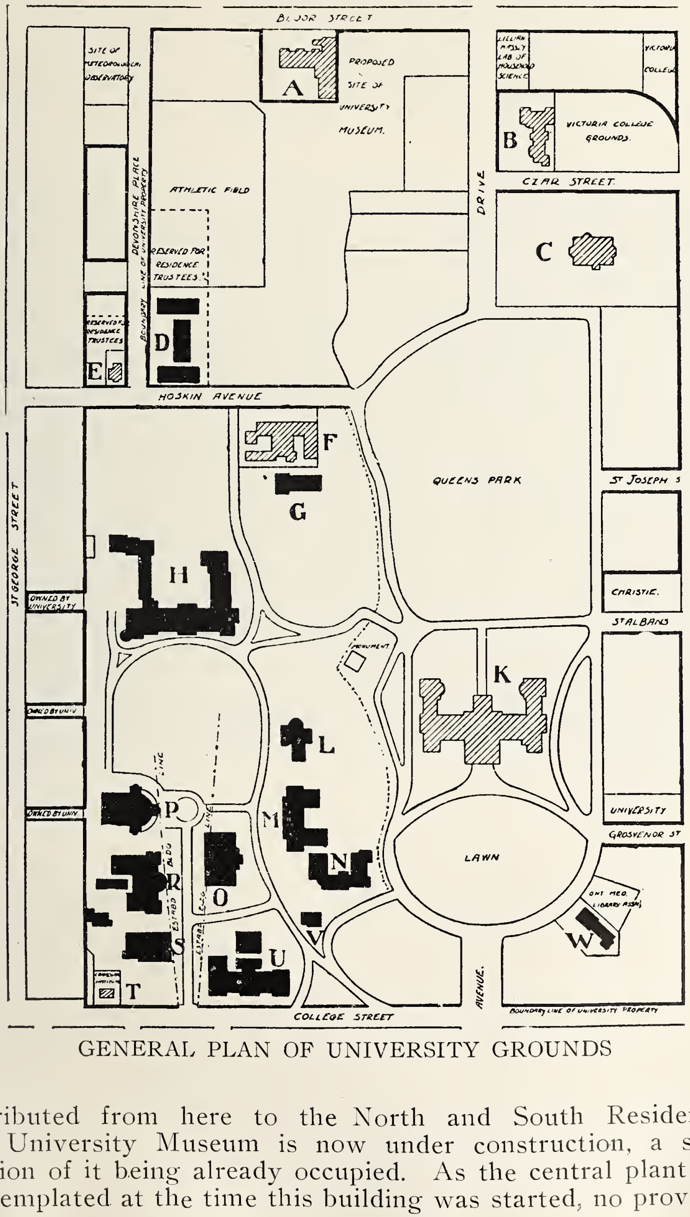
J. C. Murton.

The University of Toronto and its affiliated colleges embrace some twenty-four buildings located between College Street and Bloor Street West. The recent installation by the Board of Governors of the central plant for supplying heat, light and power to these buildings involved many difficulties attendant upon connecting the large number of buildings, all heated and lighted by different systems and from different sources. The erection of the central station near the centre of the distributing system being inconsistent with aesthetic conditions, it was deemed expedient to choose a location in the ravine between the Medical Building and the Provincial Government Buildings. In order to obscure the view of the power house from the Parliament Buildings, considerable excavation had to be done and the station is practically constructed seven-eighths below ground. The smoke-stack is some distance from the power house and is connected to it by an underground flue. This stack is so located that the addition of a proposed wing to the Medical Building will completely enclose it. In this way the power house is very effectively concealed from the view of Queen's Park.

The old method of heating the individual buildings was by separate boilers located in the basements. All of the buildings with the following exceptions used electric current from the city service: the Mining Building contained two Heine boilers and a 150 k.w. Leonard engine and generator. An emergency connection with the city service was also installed. A switchboard in this building controlled the light and power supply for the Milling, Thermodynamic and Engineering Buildings. The Milling Building was also heated from the boilers in the Mining Building. Both the Physics Building and Convocation Hall were heated and lighted from a small plant contained in a power house located in the rear of the Physics Building. This power house contained two Babcock & Wilcox boilers, a 50 k.w. and a 100 k.w. Robb-Armstrong engine direct-connected to Westinghouse generators. There was also a motor generator set for breakdown service. This power house is now dismantled and the units re-located as noted further. Convocation Hall is connected to the Physics Building by a tunnel through which the various mains are run. The main University building, known as University College, contained four horizontal tubular boilers used for heating and power. Current was generated with a small unit and light and heat supplied to the main building and to the Observatory. Connection to the Observatory is made through a tile conduit. Current was also furnished from this same source to the University residences (three buildings) and to the presi-

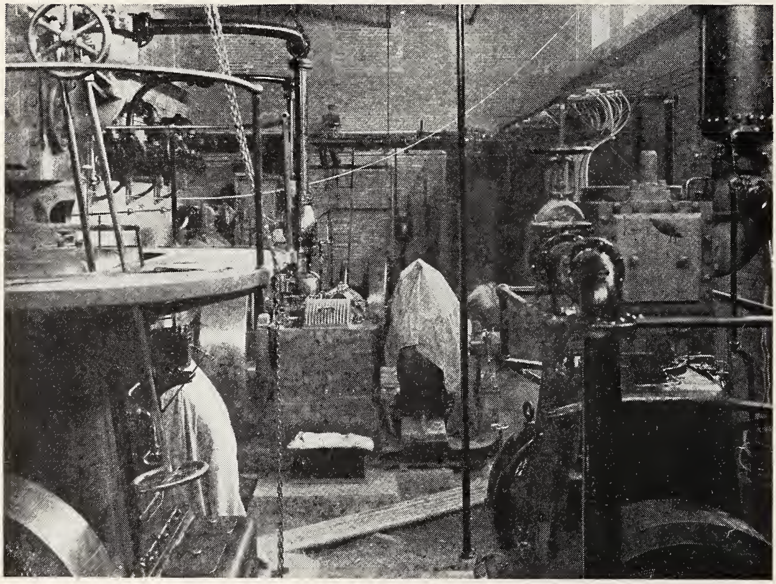
EXTERNAL VIEW OF CENTRAL STATION, THE GREATER PORTION OF WHICH IS BELOW GROUND.

dent's house on St. George Street. The three residence buildings are connected by underground passages, through which the mains are carried. The electric cables are carried to the Middle or East Residence, and current is



GENERAL PLAN OF UNIVERSITY GROUNDS

distributed from here to the North and South Residences. The University Museum is now under construction, a small portion of it being already occupied. As the central plant was contemplated at the time this building was started, no provision for obtaining heat and light other than by the central plant was made. The Victoria University group will also be heated and lighted by the University's central plant. There are four buildings in this group. Victoria University main building has been overhauled during the past summer, and fitted up for connection to the central plant. This building was previously lighted by gas, although wired for electricity. A hot air system of heating, embracing several small furnaces, was in operation. The building has been equipped with a modulation system of steam heating and has been re-wired. Burwash Hall, the men's residence, is at present under construction. This building and the adjoining dining hall, however, are depending on connection to the central plant, and no provision is being made for connection to the city mains, or for the installation of boilers.

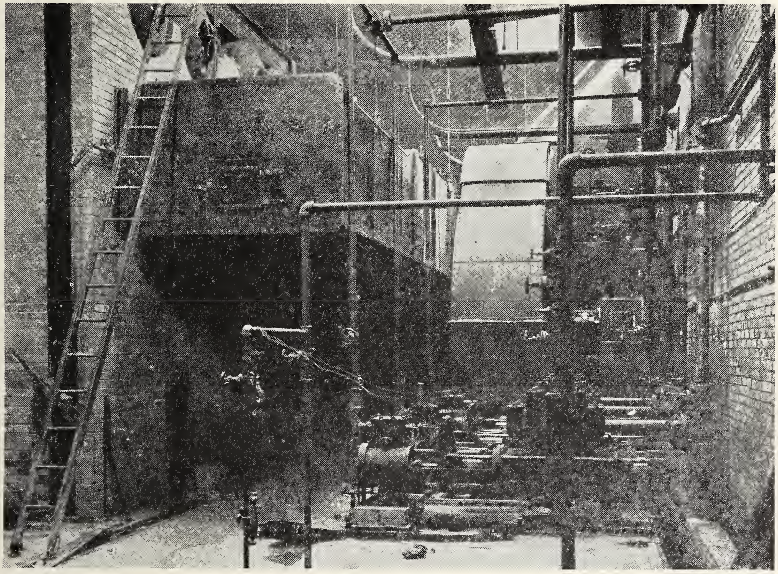


INTERIOR OF ENGINE ROOM SHOWING GENERATORS AND STEAM MAINS

Power House.

The power house, as mentioned before, is sunk almost completely in the ground. The building is divided into two parts, boiler-room and engine-room. The boiler-room contains four Babcock and Wilcox boilers, rated at 450 boiler horse-power each. Room is provided for the addition of two similar units, should this be necessary. Coal storage is provided east of and above the boilers. Coal is delivered by an inclined roadway to the roof of the power house, where a ten-ton wagon scale is provided. Coal is dumped into the storage bin, and falls by gravity into the boiler-room through two hopper scales. An electric hoist is provided in one corner of the boiler-room for removal of ashes, and delivery of supplies.

Draft for the boilers is obtained by two multivane fans driven by direct connected engines. The stack is not of sufficient height to provide natural draft for the kind of coal which is being burned. The breeching and fan connections are so laid out that should the fans be shut down for any reason, the flue gases have a straight run to the stack. Feed water is supplied to the boilers by three duplex plunger pumps. These pumps obtain their supply from the feed water heater in the engine room, and from two separate connections from the city water service.



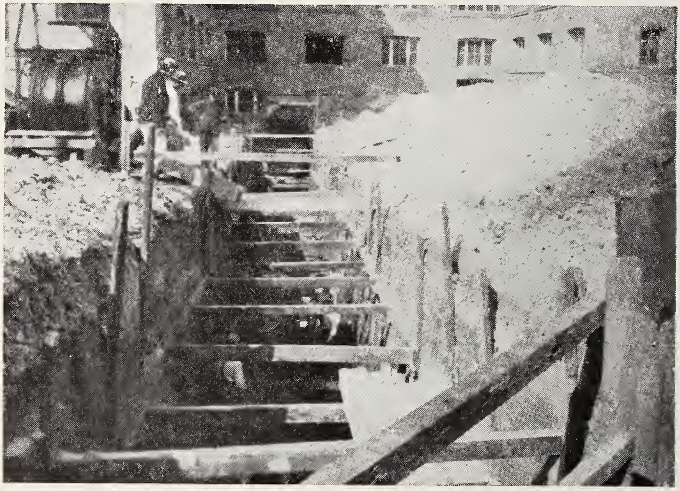
INTERIOR OF BOILER ROOM, SHOWING BREECHING AND FAN CONNECTIONS

The engine-room is equipped with two Robb engines, which were taken from the old Physics power house. A five-ton crane runs the entire length of the engine-room. This crane was also brought over from the old Physics power house. The Leonard engine and generator formerly used in the Mining Building are also installed here temporarily. This unit will be replaced by a new compound high-speed engine now under construction.

The main piece of apparatus in the engine-room is the 300 k.w. Curtis turbo-generator, which is at present carrying the total load of the plant. The generator for this unit is wound for 120-240 volt three-wire operation. The Robb engine units are each two-wire 120-volt machines, one being a 50 k.w. and the other a 100 k.w. unit.

The main steam header is carried on the east wall of the engine-room. This header supplies an auxiliary header on the other side of the wall in the boiler-room, which supplies the boiler feed pumps, injectors and fan engines.

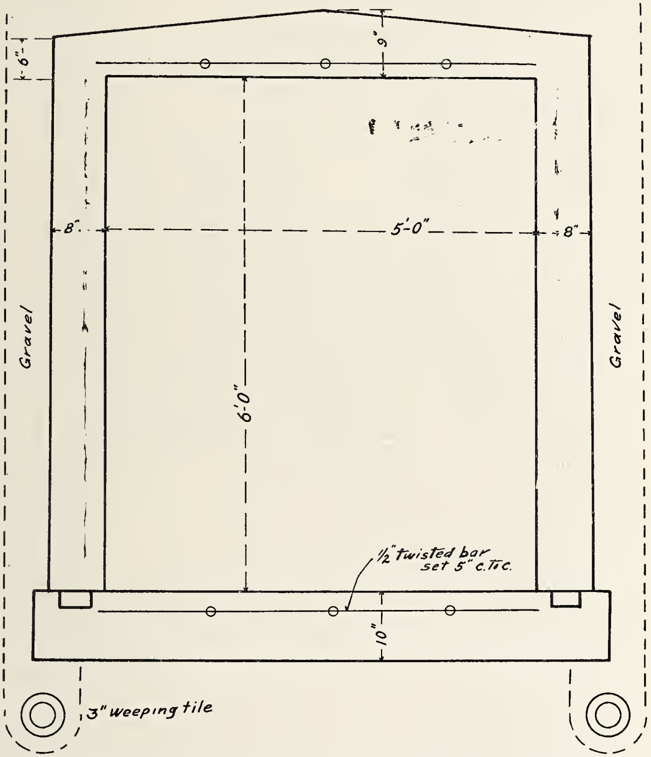
The exhaust connections from the engines are carried in a trench to the muffler tank and grease extractor. From here the exhaust is carried to a tee in the main exhaust header. One outlet from this tee is connected to the vertical discharge pipe leading to the exhaust head, and the other outlet connects to the exhaust line leading to the main heating line in the tunnel. The exhaust line is fitted with a back pressure valve which controls the pressure on the heating mains. The exhaust from the turbine is carried separately to the exhaust header. It was intended at one time to install a distilled water system for all the buildings on the plant, using steam from the turbine for this purpose. Connection is made from the main exhaust header to the feed water heater.



EXCAVATION FOR 6 x 6 TUNNEL, FROM POWER HOUSE TO MEDICAL BUILDING

The condensation returns from the steam heating system are collected in a large receiving tank, and are pumped from this tank to the feed water heater, and from there are pumped directly to the boilers.

The drips from the engines and turbine are taken care of by two main traps in the boiler room. The high pressure drips from the main header and steam separators are carried to a receiving tank, from which they are discharged to the feed water heater through a trap. The low pressure and exhaust drips, and all drips from the fan engines and pumps are carried to a receiving tank in the sump pit, from which they are lifted by a trap into the blow-off tank. A duplex pump is provided in the sump pit to take care of these drips in case of any accident to the lifting trap. A small motor-driven centrifugal pump is installed to lift the water from the sump pit to the sewer.



CROSS SECTIONS OF MAIN BRANCH TUNNELS

The switchboard is located along the west wall of the engine room. It consists of eight panels, four being generator panels, one a meter panel, and three feeder panels.

The turbine and the new 300 k.w. unit now under construction will be connected so as to carry the entire load of the plant. The two Robb engine units are connected to operate in parallel with the other units. These engines are two-wire machines, but connections have been made so that they will operate together as a three-wire unit. Special busses have been provided so that the electrical energy for experimental work in Engineering building can be supplied by these units if required. The electric furnaces in the Mining Building form part of the general load of the plant, but they may be connected directly to the Robb units by manipulating a double pole double throw switch.

Tunnels.

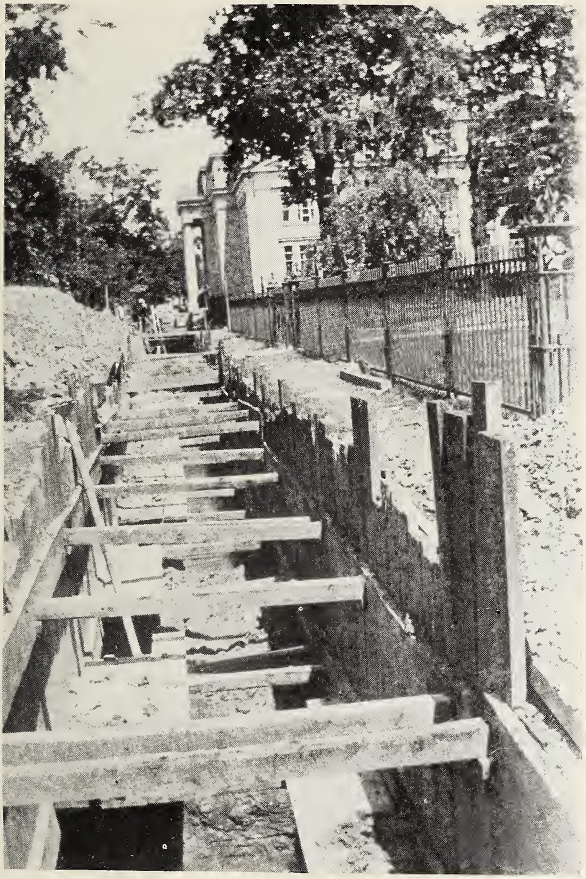
A system of tunnels connects all the buildings on the plant. These tunnels are constructed of concrete, with the roof and bottom reinforced as is shown in the accompanying figure. The main tunnel leaving the power house is 6 ft. x 6 ft. inside. The branch tunnels are 5 ft. x 6 ft. inside, and the service tunnels to each building are 3½ ft. x 4 ft. inside. The tunnels are drained from the inside by direct connection to the city sewer system through water seals and checks. Drainage from the outside is taken care of by weeping tiles running the entire length of the tunnels on both sides, and connecting to the city drainage system at various points.

EXCAVATION SOUTH OF THE ENGINEERING BUILDING, DONE IN 10 FT. SECTIONS OWING TO PROXIMITY OF FOOTINGS

The floor of the tunnels is uniformly 10 inches thick. The sides are 8 inches thick, and the roof 6 inches thick at the sides, with a 9-inch crown in the centre.

Starting from the power house, the main 6 ft. x 6 ft. tunnel runs to the Medical Building. Half-way over, a 3½ ft. x 4 ft.

connection is made to the Biological Building. From the west side of the Medical Building the tunnel runs 6 ft. x 6 ft. for about twenty feet, and then branches north and south by means of two 5 ft. x 6 ft. tunnels. The branch going south runs to the north-east corner of the Thermodynamics Building, where a branch is run west to the Physics Building. A 3½ ft. x 4 ft. branch is run from this Physics tunnel to the Engineering Building. There was already in existence a tunnel between the Physics Building, the Physics power house, and Convocation Hall, and this tunnel was used in connection with the new plant. A new 3½ ft. x 4 ft. branch tunnel was run from the Physics Building to the Chemistry Building.

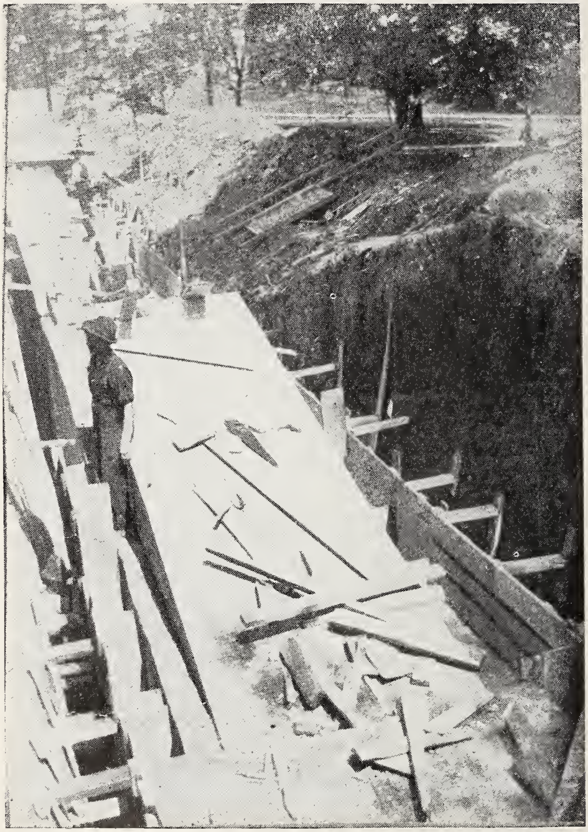


EXCAVATION ALONG AVENUE ROAD FOR DOMESTIC SCIENCE SERVICE

Going back to the north-east corner of the Thermodynamics Building, the other branch runs into the boiler-room of the

Thermodynamics Building. A 3½ ft. x 4 ft. tunnel is run from the Thermodynamics Building to the Mining Building. The Milling Building is connected to the Mining Building by underground tile conduit, in which the steam, water, and gas pipes and the electric cables are carried.

The 5 ft. x 6 ft. tunnel branching north from the junction in front of the Medical Building runs directly north to a point a few feet beyond Hoskin Avenue, with 3½ ft. x 4 ft. service tunnels to the Library, Main Building, Gymnasium, Wycliffe College, and the three University residences. The Observatory is connected to the 5 ft. x 6 ft. tunnel by tile conduit.



FORMS READY FOR CONCRETE

From Hoskin Avenue, the tunnel runs to the new University Museum. This building was constructed with a tunnel through the basement to which the main 5 ft. x 6 ft. tunnel connects. On the east side of the Museum the 5 ft. x 6 ft. tunnel continues across Avenue Road to a point opposite Annesley Hall, from which point, branches run north and south to the various buildings belonging to Victoria College. The north branch runs 5 ft. x 6 ft. to a point from which the 3½ ft. x 4 ft. service to Annesley Hall is taken off. From this same junction the tunnel continues north 3½ ft. x 4 ft. to the School of Household Science.

The south branch of the 5 ft. x 6 ft. tunnel runs to Victoria Library. The cables and heating mains are carried overhead in the basement of this building, and a 5 ft. x 6 ft. tunnel is run from the east side of the Library to Burwash Hall residences. A 3½ ft. x 4 ft. service is taken from this tunnel to Victoria College main building, and a 3½ ft. x 4 ft. service tunnel is also run to Burwash dining hall.

Entrance to the tunnel is possible through the various buildings and through manholes located at all tunnel junction points. These manholes are thirty-three inches in diameter and have inner and outer covers. At four main points, extra large manholes, 4 ft. 6 in. in diameter are provided, so that long lengths of pipe may be inserted or removed from the tunnels. Between the Library and the Main Building, where the contour of the ground made it permissible, a sloping manhole has been set. The curb and cover to this manhole are almost vertical.

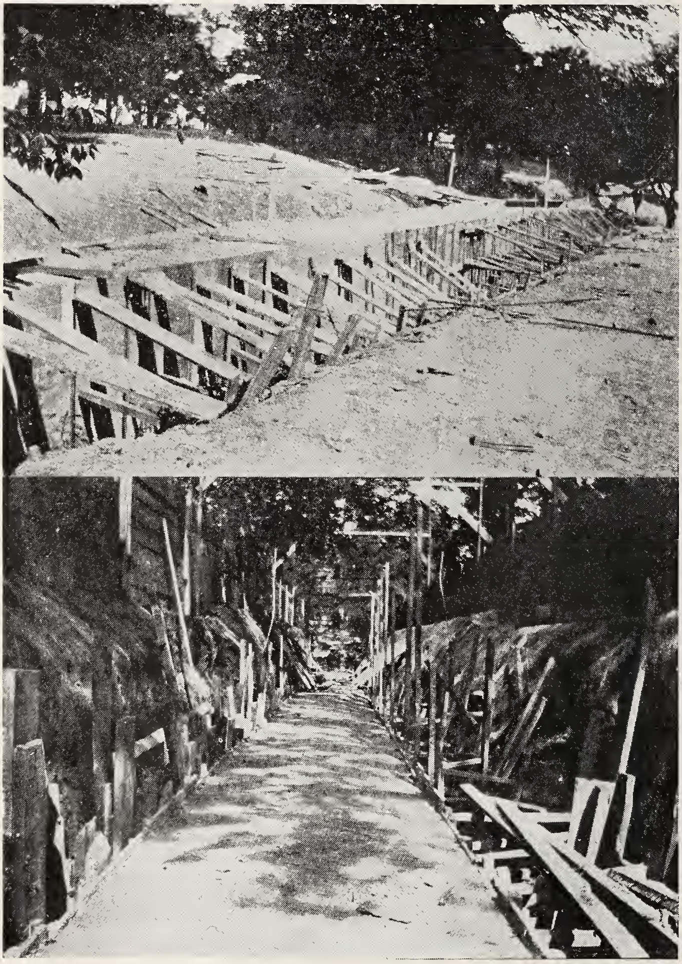
The tunnels are lighted by electric bulbs located every 125 feet, and run on a separate lighting circuit from the power house.

Electrical Distributing System.

The electrical distributing system is carried in these tunnels. The Edison three-wire system is used. Those buildings which were wired for two-wire operation were changed over to operate on a three-wire system.

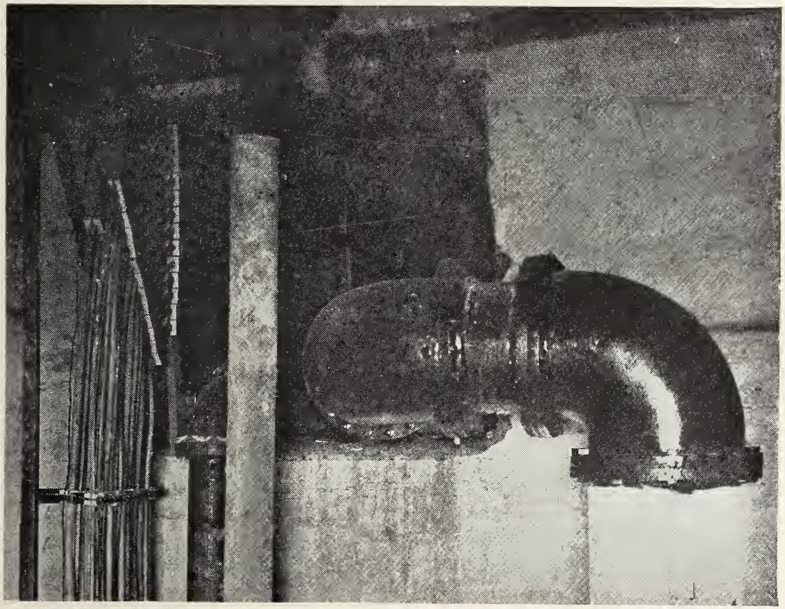
New panel boards and switchboards were provided in various buildings. The distributing switchboard in the old Physics power house was moved into the Physics Building, and wired to control the current to the Physics Building, Convocation Hall and the Chemistry Building. This switchboard contains three panels which control the heating system by means of compressed air, and one panel which controls the ventilating system. New controlling panels were provided for the Main Building and for Victoria Library.

There are thirty-one cables leaving the power house varying in size from No. 6 to 1,250,000 c.m. It might be mentioned here that considerable delay was caused in the manufacture of these cables on account of their enormous size, nothing to compare with them in size having been previously ordered in Canada. Three cables supply the Biological Building, three supply the Medical Building, five cables are run to the Mining Building, which also supplies the Milling and Thermodynamics Buildings. The Engineering Building is supplied by cables tapped onto the Mining Building feeders at the tunnel junction in front of the Thermodynamics Building. There is also a special cable run from the power house to the Engineering Building, as well as two special control wires, to be used in connection with the Electrical Engineering experimental laboratory work. Two special cables are also run to the Mining Building to supply the electric furnaces. Three feeders run to the Physics Building, which in turn supplies Convocation Hall and the Chemistry Building. Three cables run to the Library and three to the Main Building. The new control panel in the Main Building controls the supply



UPPER: METHOD OF CONSTRUCTION, WHERE NO EXCAVATION WAS NECESSARY

LOWER: VIEW OF 400 FT. RUN OF COMPLETED TUNNEL FROM MUSEUM EAST of current to the University Gymnasium and to Wycliffe College. Three cables run to the University Museum, and five to the Victoria group. Electrical connections are made to the University residences at the tunnel junction just north of Hoskin Avenue. The cables running to the University Museum and to the Victoria group are tapped, and cables run from these taps to the distributing panel in the Middle or East Residence. A panel in the Museum controls the supply to the Museum itself and also to the School of Household Science. Cables are run from the Museum direct to this building. A switchboard in Victoria Library controls the current supply to Annesley Hall, Victoria College Main Building, and to Burwash residences and dining hall.



CABLES AND PIPING, STEPPING FROM LOWER TO HIGHER ELEVATION IN MEDICAL BUILDING

The cables are carried on porcelain cleats fastened by lag screws to 2 in. x 4 in. wooden uprights bolted into the tunnel walls, 4 ft. 6 in. centre to centre. These vertical wooden supports were treated with a preservative compound before being mounted.

With a few exceptions, the cables are carried in the tunnels exclusively. Connection is made from the Engineering Building to the tunnel by tile conduit. Connection is also made from the service tunnel to the University residences through the old tile conduit formerly used to carry the cables from the Main Building to the residences.

Each generator is protected by Canadian General Electric circuit breakers. The turbo-generator is designed for 50 per cent. overload for two hours. All voltage losses or drop are calculated to be not more than 2 per cent. All switchboards are provided with Bergman recording watt-meters for calculating amount of current consumed in each individual building. On the main switchboard are located a totalizing curve-drawing ammeter and Thomson direct reading station watt-meters for each unit. All circuits on these have the usual enclosed fuse protection.

The quantity of current consumed is approximately 1,600 amperes at a pressure of 240 volts.

Heating System.

The heating system presented quite a problem, due to the different levels of the buildings and the fact that several buildings had different levels in themselves. The level of the Medical Building, being the most central, was taken as the low point of the system. All buildings whose levels were above that of the Medical Building return the condensation from the heating system by gravity.

Several buildings, however, were below the Medical Building level. These were treated as shown in the following paragraphs.

The following four points in the system were selected, and at these points gravity tanks were installed, all at the same level: one in the South Residence, one in the Main Building, one in the Physics Building, and the fourth in the Mining Building.

The condensation from Victoria University main building will be run to a pump and receiver located in the basement of the building. These returns will be pumped to a receiving tank in Burwash residences. The returns from Burwash residences and dining hall will drain to this receiving tank, and from there will be pumped to a receiving tank in the University Museum. The returns from the School of Household Science, Annesley Hall, and Victoria Library, will all drain by gravity to a tank in the University Museum. The water from these tanks will then be pumped from the University Museum to the above mentioned "gravity tank" in the South Residence. This tank then discharges by gravity into the main return line of the system.

The University residences, Wycliffe College, the Gymnasium and the Observatory all drain by gravity to the main return. The Main Building has several different water levels. These are all eliminated, and all returns are collected in a receiver in the boiler pit. From this receiver, they are pumped to the "gravity tank" in this building. This tank discharges by gravity in the same manner as the one in south residence.

The Library, Engineering, Medical and Biological Buildings all drain by gravity into the main return.

The Thermodynamics Building is heated by the exhaust steam from its experimental plant, but connection is made so that steam may be supplied from the central plant in case of a shut down of its own boilers.

The returns from the Milling Building are carried to a receiver in the Mining Building. When the Thermodynamics Building is taking steam from the central plant, the returns from this building will also be collected in the receiver in the Mining Building. These returns are pumped to a "gravity" tank on the second floor, and drain from there to the power house.

MAIN STEAM LINE, LAID ON CONCRETE FLOOR, NORTH OF HOSKIN AVE.

The condensation from Convocation Hall, Chemistry Building, and Physics Building is collected in a receiver in the Physics Building and is pumped from there to the third "gravity tank," and drains from this tank to the main return line in a manner similar to the others.

The steam that will be furnished from the exhaust of the turbine, the engines, and other equipment of the power house is not sufficient to supply the entire heating load. Provision, therefore, had to be made to supply live steam from the boilers direct to the system, whenever the pressure in the heating main drops below a certain point. A high pressure "booster" line is also carried in the tunnel, paralleling the supply and return heating mains. This booster line furnishes live steam to all the buildings for hot water heating service, and to certain buildings for steam tables, kitchen cooking apparatus, experimental work, etc. The exhaust steam heating main is also connected inside the buildings through pressure reducing valves to this booster line, as a further precaution to insure plenty of steam for heating.

Valves have been installed and piping connections have been made to all buildings so that steam can be shut off at any time from the central plant, and the buildings heated by their individual boilers.

The steam used for heating is measured by the condensation returned to the system. Each building is provided with a condensation meter which measures all water returned to the system through the building. A meter on the main return line just outside the power house measures the total amount of water returned to the receiving tank in the power house.

All condensation in the booster line is discharged through traps into the main return line. All condensation in the exhaust steam heating line is collected at various points and discharged into the return line through lifting traps.

H. W. Tate, '09, is on survey work for Chas. E. Goad Co., civil engineers, Toronto.

C. G. Titus, '10, is engineer for the Hudson Bay Mines, Cobalt, Ontario.

H. W. Tye, '08, is in the Construction Dept., Canadian Pacific Railway shops, Winnipeg.

M. B. Watson, '10, is resident engineer on sanitary and hydraulic work for Chipman & Power, at Neepawa, Man.

Mr. J. B. Challies, '04, has recently been appointed hydraulic engineer of the railway lands branch of the Department of the Interior.

Mr. R. G. Swan, '09, who has been engaged on water power investigations on the Winnipeg River, has joined the engineering staff of the British Columbia Electric Railway Co. at Vancouver.

Mr. T. H. Hogg, '07, is managing editor of The Canadian Engineer, succeeding Mr. James, '04, in that capacity. Mr. Hogg was previously engaged in the design and construction of the new works of the Ontario Power Company at Niagara Falls. Mr. James, upon severing his connection with editorial work, took up his duties as engineer for the Board of Highway Commissioners, York County, and as engineer for the town of North Toronto.

ELECTROCHEMICAL AND ELECTROMETALLURGICAL DEVELOPMENTS IN CANADA.*

S. DUSHMAN, B.A., Ph.D.

The number of electrochemical plants at present in operation throughout the Dominion of Canada is not very large. The reasons for this state of affairs are not far to seek. Up to the last decade the history of the country has been practically the story of the struggles of pioneers with the difficulties and disappointments which must always confront men in a new land. The toil of the soil, no matter how fertile it may be, is sufficient to engross in itself the attention of a small and scattered community. But the discoveries, made within the last few years, of rich mineral wealth in different parts of the country, and the exploitation by three trans-continental railroads of the vast prairies of the West, have led not only to a phenomenal growth in population but also to an influx of capital from both the United Kingdom and the United States which promises well for the electrochemical future of the country.

In the following paper the discussion of the electrochemical and electrometallurgical developments of Canada has been divided into two parts. The first part contains descriptions, as far as available, of the different electrochemical plants at present in operation, the second part is devoted to a survey of the mineral resources of the country and their possible exploitation by electrochemical methods.

PART I.

We shall begin at the extreme west, in the province of British Columbia. The great Cordilleran ranges, whose peaks often reach as high as 20,000 feet above the sea level, condense enormous masses of snow, which by their annual melting serve to feed many small torrents as they come rushing down to empty into the great rivers of the lower valleys. One such tributary is the Kootenay, whose length is about 350 miles, and which drains an area of 9,800 square miles.[1] At Bonnington Falls, which is situated ten miles below the city of Nelson, the river has a minimum flow of 5,850 cubic feet per second, with a natural drop of about seventy feet. In the months of June and July, when the snow melts, the flow rises as high as 60,000 cubic feet per second. At this point the West Kootenay Power and Light Company has erected two plants, the older one with a capacity of 4,000 H.P., and a later one, in which two 8,000 H.P. turbines are installed. From the latter, power is transmitted at

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* Paper presented at the 20th meeting of the American Electrochemical Society, Toronto, Sept. 22, 1911.

(1) Report 24, Department of Mines, Ottawa. The mining and metallurgical industries of Canada (1908) p. 225.

22,000 volts to Rossland and Trail (the latter being twenty-eight miles distant), and at 60,000 volts to Phoenix, at a distance of 79 miles, Grand Forks, 69 miles away and Greenwood which is farthest at 83 miles.[2] "Most of this power is used in mining and smelting work and for the lighting requirements of mining towns." Besides these plants the company operates another plant on the Kettle river, about 12 miles below the town of Grand Forks, where the head of water is 156 feet. The average cost of electric power throughout the area covered by the lines of the West Kootenay Power and Light Company does not exceed one quarter the cost of steam power.[3] The result has been that throughout the whole of the Boundary district, steam power is a thing of the past.

The Trail Lead Refining Plant.

As already mentioned, a large portion of the power from one of the plants is sent to Trail where the Consolidated Mining and Smelting Company of Canada operates a plant for smelting copper and lead ores from its numerous mines. The lead bullion produced by the smelting operation is cast into anodes and refined by the well known electrolytic process of Mr. A. G. Betts.[4] The object in refining the lead is to recover the copper, antimony and bismuth, as well as the gold and silver contained in the bullion. The metal is melted in a large iron tank of 50 tons capacity, and the dross, which forms on the surface, carries away most of the copper, while the fused metal is pumped by an electric centrifugal pump to the anode moulds. The anodes, which contain 97.9 to 98.4 per cent. lead are each 30 inches wide, 31 inches deep, and vary in thickness from 1½ inches at the top to ⅞ inch at the bottom, the wedge-shape being used to facilitate extraction from the mould. Side lugs project at the top to permit suspension from the bus bars into the tank. The weight of each anode is about 400 pounds. There are 22 of these placed on a car and trammed to position alongside the tank. They are then placed in position in the tank by an electric crane, so that one cathode is situated between two anodes.

Each cathode consists of a thin sheet of refined lead, weighing about 20 pounds. The top edge is wrapped around a copper bar for the purpose of suspending across the bus bars. All the cathodes are connected to one of the bus bars running along the top of the tank, while all the anodes are similarly connected to another bus bar.

The tanks are about 6 feet 4 inches long, 2 feet 6 inches wide, and about 3 feet 6 inches deep. They are made of wood bolted together, and coated with tar inside.

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(2) J. N. Pring, Some Electrochemical Centres, p. 51.

(3) Report 24, p. 225.

(4) Literature on Lead Refining at Trail:—
J. N. Pring, Some Electrochemical Centres, p. 53.
A. G. Betts, Lead Refining by Electrolysis.
M. de K. Thompson, Applied Electrochemistry, pp. 64-6.
Report 24, pp. 242-3.

The electrolyte is a solution of lead fluosilicate containing an excess of hydrofluosilicic acid.

Hydrofluoric acid (HF), prepared by treating fluorspar (CaF_2) with sulphuric acid, is allowed to trickle through a layer of broken quartz or pure silica sand thus producing hydrofluosilicic acid. The latter is then neutralised with white lead. As the electrolyte continually tends to dissolve an excess of lead from the electrodes and thus lose its acidity, it is found necessary to add free acid from time to time. The average composition of the electrolyte is stated to be as follows:—

H_2SiF_6	9.5 to 10.5%
Pb (as $PbSiF_6$)	4.5 to 5.2%
Specific gravity	1.13 to 1.16

One of the most remarkable features of the process is the fact, discovered by Mr. Betts, that the addition of a slight amount of glue to the electrolyte leads to the formation of smooth coherent deposits at the cathode.

The usual current density employed is 16 to 18 amperes per square foot, a total current of 3,100 to 3,600 amperes at 70 volts being supplied to two parallel sets of 90 cells. During the electrolysis, lead, iron, zinc and nickel go into solution, but owing to the small amounts of the last three constituents, and the acidity of the bath, only the lead is deposited on the cathodes. The other constituents of the anode metal, such as the precious metals, copper, and antimony, go into the slimes. The average composition of the slimes is as follows:—

Lead, 10 to 18%; Arsenic, 23 to 28%; Antimony, 21 to 27%; Copper, 7 to 22%; Iron, 1 to 2%; Silver, 5%.

After the electrolysis, which is allowed to proceed until about 75 per cent. of the anode is dissolved, the cathodes are washed, melted, and cast into ingots. The slimes are washed and then treated with a solution of sodium sulphide, thus dissolving antimony and arsenic. The solution is electrolysed for the recovery of antimony in cells containing iron cathodes and lead anodes. The antimony deposited on the cathodes is melted under a flux of antimony oxide and sulphide and gives bars of pure metal. The residue from the sodium sulphide treatment containing silver, copper and gold, is dried and roasted, and then boiled with a solution of sulphuric acid which dissolves the copper and silver. The resulting solution goes to precipitating tanks where the silver is precipitated by copper. The resulting silver assays 999.5 fine, and is sent to the Royal Mint at Ottawa, as well as other mints. The solution from the precipitating tanks is evaporated to the proper density and copper sulphate crystallized out. The gold left in the parting kettles has a fineness of 995.

The refined lead is 99.989 per cent. pure. While a small amount of it is used for the manufacture of lead pipe at Trail, most of the refined metal finds its way to the producers of white lead.

The plant at Trail was the first of its kind on the continent, and was installed in 1902 with a daily capacity of 50 tons of refined lead. Since that time its capacity has steadily increased, and at present it is producing approximately 100 tons per day. An idea of its output may be gathered from the following statistics: During 1909 the total production of pure lead was 41,883,614 lbs., together with 18,241 ozs. of fine gold, 2,003,003 lbs. fine silver and 51,405 lbs. of copper sulphate recovered from the slimes.[5]

There are no other electrochemical industries in the province at the present time.

Proceeding towards the east, the greatest development in electro-metallurgical and electrochemical industries has occurred in the Province of Ontario.

Calcium Carbide.

The oldest electrochemical industry in Ontario is the manufacture of Calcium Carbide. The Willson Carbide Co., located at Merriton has been in operation since 1897.[6]

"The Company uses as raw materials lime, coke and coal. The lime is obtained from the quarries near Port Colborne, and contains about 92 per cent. of calcium carbonate. The coal and coke are imported from Pennsylvania. The raw materials are first ground in rotary crushers and rolls, and then mixed in the proper proportions and delivered by conveyors and chutes to electric furnaces. The furnaces, slightly conical in shape, are filled gradually, the charges being weighed and fed at stated intervals. [About 100 parts of lime are used to 70 parts of carbon.]

Calcium carbide is formed by the fusion of the raw materials in the electric furnaces. The fusion requires a current of from 2,500 to 3,000 amperes, at a constant pressure of 75 volts. The voltage is regulated automatically by raising or lowering the electrodes. After fusion the furnace is dumped, and the unfused material retreated. The carbide is obtained in the form of a solid fused mass which is crushed and bolted and finally packed into steel receptacles, each containing 100 pounds. There are in all, six electric furnaces in operation, the power for which (1,200 H.P., three-phase) is supplied by three power stations, on the Welland Canal close by. The total yearly capacity is 1,200 tons of carbide." The cost of the power is said to be very low.

The Ottawa Carbide Co., which also utilizes the same process is located on Victoria Island, in that section of Ottawa known as the Chaudiere. The capacity of the plant is 3,000 to 4,000 tons per annum. The electric power is taken from the Ottawa Power Co. The lime, containing 93 to 96 per cent. CaO is derived from Rockland, 38 miles from Ottawa, while the coke used comes entirely from Pennsylvania. The works contain 20 furnaces.[7]

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(5) Report 88, Department of Mines. The Mineral Production of Canada during 1909, p. 27.

(6) Report 24, p. 515.

(7) According to the Report of the Bureau of Mines of Ontario for 1909, each furnace required at that time about 200 H.P. It is hardly likely that the capacity per furnace has remained at this figure during the past decade, as 500 H.P. furnaces are quite usual in the United States.

The annual output of both plants for the period 1905 to 1909 has averaged approximately 2,500 tons.[8]

Ferro Alloys.

The work of Drs. Haanel and Heroult on the electric smelting of iron and steel has had the direct effect of stimulating at least two companies to embark on the manufacture of ferro alloys by the electrothermic process.

After the completion, in 1907, of the Government experiments at Sault Ste. Marie, the Lake Superior Power Co. bought the experimental plant from the Government and used it for the manufacture of ferro-nickel pig from pyrrhotite.[9] At the present time it is utilizing the furnace to produce ferro-silicon for its own consumption.[10]

The other company which is engaged in the manufacture of ferro-silicon is the Electro-Metals Co., at Welland. The company owns about 40 acres of land to the south of the town, on the east side of the Welland Canal. The iron ore is imported from the United States, and silica in the form of rock or flint is brought from Frontenac or Parry Sound district.[11] The Company has four furnaces of from 1,000 to 1,500 H.P. each, the daily production being 5 to 8 tons. The power is obtained from the Ontario Power Co.

Cyanamide, Graphite and Silicon Carbide.

The low cost of power on this side of the Niagara River has led to the establishment of three industries, in each of which power consumption is the chief item of cost.

The **American Cyanamide Company,** located near Niagara Falls, Ont., manufactures calcium cyanamide by the process of Frank and Caro. Nitrogen is passed over heated calcium carbide in closed retorts. The result is the formation of a substance having the formula $CaCN_2$ and known as cyanamide. Investigations at numerous agricultural stations have shown that it can be successfully used as a fertilizer, and the whole of the product manufactured at Niagara Falls is at the present time finding a market in the United States. The cyanamide is not sold as such, but is previously mixed with Chili saltpeter.

The nitrogen for the process is obtained by passing air over heated copper, which is subsequently regenerated by natural gas. The power is obtained from the Ontario Power Co. The Cyanamide Company commenced operations in January, 1910, with a 10,000 ton plant. This is at present producing to its full capacity.

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(8) Report 88, p. 242.

(9) Report 16, Experiments made at Sault Ste Marie, under Government auspices, in the smelting of Canadian ores by electro-thermic process. Final Report on —— by Eugene Haanel, Ph.D., 1907. Pring, some Electrochemical Centres, pp. 73-4.

(10) Report 88, p. 68.

(11) Ontario Bureau of Mines, 1910, p. 30.

The **International Acheson Graphite Co.,** has also established a small plant in the same locality. Its output in 1909 was 513,436 lbs.[12] Incidentally it may be mentioned that both Ontario and Quebec have large deposits of natural graphite. In 1909 the exports from mills in the two provinces amounted to 2,000,000 lbs., valued at $53,302.

The **Norton Company of Niagara Falls, N. Y.,** has a plant at Chippawa for the manufacture of **crystolon.** The latter is a trade name for carbide of silicon. The electric furnace used is probably of the same type as that used for the manufacture of carborundum. A core of coke is surrounded by a charge containing a mixture of sand, coke and sawdust, the latter being added to make the charge porous and thus facilitate the escape of carbon monoxide gas. The current passing through the coke heats up the surrounding charge to a temperature at which the coke and silica react to form SiC, silicon carbide or carborundum. The raw materials used are two different grades of coke (a metallurgical coke with 92% or more fixed carbon and 5% ash, and a petroleum coke, containing about 91% fixed carbon with less than 1% ash), a very pure silica sand, and sawdust. Two grades of product are manufactured, green and steel grey. The power is derived from the Ontario Power Co., and amounts at present to 2,000 H.P., which is received at 12,000 volts and transformed to 145 volts, after which it passes through induction regulators which buck or boost the voltage to 70 and 215.

The whole of the production, which amounts to over 5 tons per day, is shipped to the company's main works at Worcester, Massachusetts, where it is manufactured into different abrasive articles. (For this information I am indebted to Mr. L. E. Saunders of the above company).

Electrolytic Alkali.

An electrolytic alkali industry was attempted about twelve years ago by the Lake Superior Power Co.[13] Among the many subsidiary organizations initiated by this company was the Canadian Electrochemical Co., for the electrolytic manufacture of caustic soda and bleaching powder. One hundred and twenty cells of the Rhodin mercury type were installed, each cell utilizing 1,000 amperes at 5.5 volts. The total capacity of the plant was 4.5 tons of caustic and 9 tons of bleaching powder per day. The salt was obtained from wells in the County of Huron. This plant has, however, been out of commission for a number of years.

At the present time the Canadian Salt Co., of Windsor, Ont., is erecting a plant at Sandwich for the manufacture of caustic soda electrolytically. It is expected that this plant will begin operations very shortly.

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(12) Report 88, p. 197.
(13) Ontario Bureau of Mines, Report for 1901, pp. 61-8. Pring, pp. 48-50.

The Electrolytic Refining Plant and the Ottawa Mint.

The electrolytic refining plant at the Royal Mint, Ottawa, is a recent electrochemical development in this country. For the description of this plant I am indebted to the kindness of Dr. James Bonar, Deputy Master of the Mint.

The gold bullion (after being assayed) is melted with silver in such proportion as to form an alloy containing 40% gold, 56% silver, and 4% base metals. This alloy is cast into anode plates approximately 15 inches long, 3 inches wide, and ⅜ inch thick. Forty-four of these anodes are suspended in a tank containing dilute solution of silver nitrate and a little nitric acid, and the silver deposited out on pure silver cathodes suspended at a distance of 2½ inches from the anodes. When nearly all the silver is removed, a spongy mass of gold is left retaining the original shape of the anode plate. This is removed, washed with hot water, melted and cast into wedge shaped plates 8 inches long, 3½ inches wide, ½ inch thick at the top tapering to ¼ inch at the bottom. The anodes containing approximately 96% gold are then refined further by the Wholwill electrolytic method, a solution of gold chloride and hydrochoric acid being used as electrolyte and strips of pure gold 2½ inches wide, 10 inches long, and 15–1,000 ths of an inch thick as cathodes. The deposited gold is 99.90 to 99.95% fine and is melted into ingots of about 500 ozs.

The power for the deposition is obtained from a direct coupled motor and generator which is capable of supplying 225 amperes at 30 volts when the two windings are in series, and 450 amperes at 15 volts when in multiple. When fully equipped the refinery will have 10 silver and 10 gold cells producing (with ordinary working hours), 20,000 ozs. of fine gold a month. At the present time the output is somewhat less than half that amount. Most of the gold treated in the refinery naturally comes from the Yukon.

Electrochemical Industries in the Province of Quebec.

Most of the electrochemical industries of Quebec are situated around Shawinigan Falls. This falls is situated about 85 miles east of Montreal on the St. Maurice River. A fall of about 150 feet in the waters of this river has been utilized by the Shawinigan Falls Power Co. to develop about 25,000 H.P., most of which is transmitted to Montreal by an aluminum line at 50,000 volts.[14] The town of Shawinigan Falls has been laid out with a view to the erection of a model manufacturing town, and it is therefore only natural that such a point should be chosen for the location of electrochemical industries.

The Northern Aluminum Co., a branch of the Aluminum Co., of America, was the first industry to establish itself at Shawinigan Falls. Owing to the necessity of using direct current at low voltage, "It was considered better to generate the power as direct current.

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(14) Montreal Electrical Handbook, p. 121. Pring, p. 40.

The company therefore take their supply of water from one of the penstocks leading from the canal of the Shawinigan Water and Power Co., and are expected to take the capacity of another penstock."[15] The plant covers an area of about 10 acres. The process used is the well knownelectrolytic process of Chas. M. Hall. Alumina (Al_2O_3) dissolved in a molten mixture of the fluorides of aluminum and sodium (or potassium) is electrolysed in a cell consisting of an iron trough lined with carbon, which serves as cathode. The anode is composed of a large number of carbon rods dipping into the charge. The current passing through the fluorides fuses them, and decomposes the alumina, depositing aluminum on the bottom of the cell and liberating oxygen at the anode. Fresh alumina is added from time to time to make up for the amount decomposed. The alumina is prepared from bauxite in the East St. Louis (Ill.) plant of the parent company. "There are 340 cells in operation, each producing, on an average, 150 lbs. of aluminum, 99.4% fine, per day."[16] The total capacity of the works is 25 tons of aluminum per day, about 500 men being employed when the plant is running at full capacity. The output in 1909 was over 3,100 tons.[17]

The plant of the Shawinigan Carbide Co., is situated at a distance of two miles from the power house of the Shawinigan Water and Power Co. The electric furnaces are continuous; the manufactured carbide is drawn off in pots, and the fused mass, after cooling is broken up and granulated in mills. Eight furnaces have been installed, two of which require each 1,500 H.P., and the remaining six require each 750 H.P. for their operation. The combined capacity of the furnaces is 25 tons of carbide per day, requiring a total of 7,500 H.P. About 100 men are employed.

Besides these two plants at Shawinigan Falls, the Electro-Reduction Co., of Buckingham, manufacturers phosphorous and ferro-phosphorus from apatite. No details are available as to the nature of the plant.

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(15) Handbook, p. 137.
(16) Report 24, p. 424-5.
(17) Report 88, p. 133.

[NOTE.—The second part of this paper will deal with a review of Canada's mineral resources and the adaptation of electrochemical methods for their exploitation, and will appear in an early issue of this journal.—Ed.]

D. D. McAlpine, '09, is in electrical work at Kakabeka Falls, Ont.

A. G. McLeish, '11, is in the employ of the Mond Nickel Co., Victoria Mines.

J. McNiven, '10, is with the Dominion Bridge Co. in their Winnipeg office.

A. B. Manson, '09, is divisional engineer for the Canadian Northern Railway at Biscotasing, Ontario.

F. H. Moody, '08, is managing editor of the Railway and Marine World, Toronto.

TORONTO MEETING OF THE AMERICAN ELECTRO-CHEMICAL SOCIETY.

The twentieth general meeting of this society was held at the University of Toronto from Sept. 21st to 23rd. There were three professional sessions held for the reading and discussion of papers. All were well attended and many instructive papers were presented. Dr. W. R. Whitney presided at the session.

"The Recent Progress in Electrochemical Iron Smelting in Sweden" was the subject of a paper read by Mr. T. D. Robertson, of the Canadian Böving Co., of this city. It may be summed up as follows:

1. Electric smelting of iron ores is no longer in the experimental stage, but in Sweden is thoroughly established on a commercial scale.

2. The smooth and regular working of the furnace at Trollhattan has been a marked feature, probably less trouble being experienced than would have been the case with a blast furnace doing similar work.

3. The quality of iron produced for steel-making purposes has been shown to be equal, and in some cases superior to that of Swedish blast furnace pig iron.

4. The comparative costs of electric and blast furnace smelting depend in general on the cost of suitable fuel and electrical energy, as the electric furnace simply substitutes one electrical h.p. year for two metric tons of blast furnace fuel. In Sweden there is no doubt that the electric furnace has come to stay on account of cheaper production.

5. The electric furnace is specially adapted to the smelting of finely divided ores or concentrates.

6. Electric smelting in Sweden has a national value as its adoption will result in the development of water powers which could not in many cases be profitably utilized for any other purpose.

Mr. F. A. J. Fitzgerald, of Niagara Falls, N.Y., presented a paper dealing with an unsuccessful furnace experiment, which proved very interesting. In the discussion which followed Dr. Whitney emphasized that the description of unsuccessful experiments should be encouraged for the valuable lessons which they teach.

"Titanium in Iron and Steel" was the subject of a paper by Mr. C. V. Slocum of the Titanium Alloy Manufacturing Co. of Pittsburg, Pa.

Other papers presented were:—

"Production of Molybdenum Steel in the Electric Arc."

"Niagara Transforming Stations."

"Design of a 30-ton Electric Induction Furnace."

"Addition Agents in Electrolytic Copper Deposition for Solutions containing Arsenic."

"Conductivity of Mixtures of Copper Sulphate and Sulphuric Acid."

"Transformation of Other Forms of Carbon and Graphite."

"Electric Laboratory Furnace with Resistor of Ductile Tungsten or Molybdenium."

"Electric Properties of Sodium, Potassium, and their Alloys."

"Electric Resistivity of Iron Alloys."

"Metallic Cerium."

"Thermal Conductivity and Convexion in Gases and High Temperatures."

"Measurement of Small Gas Pressures."

"The Electrochemical Industries of Norway."

"Electric Nickel Smelting."

"Galvanizing Wire in Zinc Dust."

"Electrochemical and Electrometallurgical Developments in Canada," which appears in this issue of Applied Science.

All papers, although decidedly technical, were extremely interesting and represented a great volume of work and investigation. Lively discussion followed each paper, and many points were brought up which otherwise might have been passed over.

Mr. J. B. Gibson, of the Ontario Bureau of Mines, gave a very interesting talk on the mineral resources of the Province of Ontario.

With the aid of a map the author sketched the situation and geology of the different portions of Ontario, and gave an account of the mineral resources which have been found or may be expected to be found in these different portions. In Eastern Ontario there is a great variety of ores, but Northern Ontario is the real home of the metallic deposits.

Mr. Gibson discussed at some length the production of silver, nickel, and gold in Ontario. There have been two eras of silver production in Ontario; the present one began with the opening of the Cobalt mines in 1904.

The nickel industry depends on the nickel-copper ores in the Sudbury district.

The gold industry is at present widely scattered, and while it is not yet very successful, it may be expected to become of great importance in the future.

Mr. Gibson concluded by suggesting two problems of importance which might be solved by electrochemical means. The first had to do with corundum, which is practically pure alumina, and is used at present mainly as an abrasive. But it is a richer ore of aluminum than bauxite, and a process of making aluminum from corundum would be very profitable.

The second problem is the possible recovery of potash. There are deposits of feldspar in Ontario containing 13 to 14 per cent. of potash. If the potash could be gotten out of it we would be able to get independent of Germany, which has at present the monopoly in potash salts.

In the discussion Dr. Whitney remarked that another problem which might be worked out profitably is a process for the complex cobalt silver ores.

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EDITORIAL

VOLUME FIVE
NUMBER ONE

Volume V. of Applied Science begins with this issue. In the twenty-fifth appearance among the graduates of the monthly journal into which the Engineering Society saw fit to mould the old Transactions, it is only necessary to repeat that by keeping the graduates in closer touch with the institution, Applied Science has performed the important function for which it was intended. Our aim is to preserve and to further promote this duty, to expand and develop, so as to keep pace with the expansion and development of field among the increasing number of graduates and among Canadians engineers generally.

It is true that an engineer's professional work often leaves him little time for devoting attention to the many things which would give him pleasure. Chief among these is his interest in his Alma Mater. The absorbing tendency of modern business obligates him to overlook this duty at times, unwillingly though it may be. Therein lies the danger of the graduate losing interest in the university.

Applied Science will co-operate with graduates of the Faculty of Applied Science in any endeavour they will make to strengthen the ties that tend to sever. The Engineering Alumni, the S.P.S. Club in Northern Ontario, the U. of T. Club of New York, and the U. of T. Club of Pittsburg have all done a vast amount of good work in this respect. But it has been of a local nature and has not the far-reaching advantages of this publication. Its appearance monthly, containing papers of interest and instruction, as well as news of the progress of the University in general and the Engineering Society in particular, together with its wide circulation throughout Canada, makes it most suitable for this work.

We want to keep in communication with all graduates; to receive from them news of their professional achievements, papers for publication of improved methods of manufacture, types of construction, results of investigation, and general engineering items of interest to "School" men of the past and present. We also want the graduates to consider our advertisers when in the market for their products. They have the materials to suit your needs. Their reliability is unquestionable. By patronizing them you are materially aiding Applied Science.

Finally, we wish to express our appreciation to a number who have remitted one dollar in advance of the appearance of the first number of this volume in payment of their subscription. Subscriptions are now due. A stock of special binders to hold the six issues are being prepared, and will be furnished free to paid subscribers. The advantage of having one of these binders to preserve your copies as they appear is obvious. It will likewise minimize the call a few years hence for back numbers for incomplete volumes. We regret that we are now unable to supply several back numbers, but look to these binders to lessen the number of requests for them in future. Readers may well consult their own convenience in this matter.

TO FIRST YEAR MEN

First, to the class of 1915, we would tender a reminder of the address given by President Falconer at the opening of the college term. Its beginning marked an epoch in your life's work. You may consider it a serious matter, or, possibly, some may think lightly of it. Your academic course has been completely mapped out for you, and you will find it advantageous to adhere to it as closely as possible. It will take up the greater part of your time, but no more of it than is necessary for the completion of the year's work. The curriculum was not compiled with the intent that you should devote your entire time to study.

There are enough activities in the University of Toronto to keep everyone busy. It is to your own interest to consider again the advice given you as to securing the full value there is in a college course.

The paper presented by Mr. E. H. Darling, '98, at a recent meeting of the Engineering Society, is one of much value to the undergraduate. It displays a number of points not previously thought of by them as entering into the design and construction of this type of building. The "stand for ages" idea is not so important as the quality of adaptability to alterations, in the problem of real efficiency when applied to them; this is one of the many points which scientific study of industrial requirements lays bare.

ARTICLES IN THIS ISSUE

Such a treatment of the subject as has been given it by Mr. Darling, is invaluable to engineers and manufacturers among our graduates, to whom these problems frequently appear in concrete form. The problems of utility, location, and finance have confronted them in building construction, and they are doubtless ready to endorse the qualifications required in the Industrial Engineer and the definition of his work as set down in this paper.

The phenomenal growth in the variety and extent of the industries of Canada during the past quarter century surpasses by a wide margin that recorded in the history of any other country. The progress in city and railway building, in land and mine development, is so largely in the fore at this period that the older established industries are many of them lacking the publicity previously bestowed upon them.

One of the newer industries of the country is aptly described in Dr. Dushman's paper, dealing with the application of electrochemistry and electro-metallurgy. As has been the rule in Canadian progress, the introduction of the methods therein discussed is in keeping with the growing need of caution against wasteful tactics in the treatment of minerals and in the utilization of bye-products. The electrolytic refinement of the rarer metals, the manufacture of calcium carbide, ferro nickel, ferrosilicon, graphite, carborundum, cynamide, caustic soda, ferrophosphorus and aluminum, are among the new branches that are offshoots of the scientific investigation of the agency of electricity in effecting chemical change. It suffices to say that the list, although not lengthy as yet, shows that the industry is on a firm basis in Canada, which is proven by statistics relating to the output of the concerns already established. Owing to the wide field, great progress will be made as the applications increase in number and broaden in extent.

In this number, a paper appears, dealing with the installation of a central heating, lighting, ventilating and power service for the whole group of buildings comprising the University of Toronto. The construction of this system has been in progress since May, 1910, and the knowledge of its completion, with the return of lawns and walks to their normal state, is very gratifying. The excavation of some 295,000 cubic feet of earth for the construction of 5,875 feet of tunnel gave the grounds an unsightly appearance for a considerable length of time. An idea of the magnitude of the undertaking of which this tunneling formed a part is clearly given in the article and the illustrations which accompany it. This plant will effect a great economy in the heating and lighting of the University buildings. Hitherto in each of the college buildings there has been a heating outfit and this, of course, involved the maintenance of one or two men in connection with each. Several of these plants had been in commission for a great length of time, and they were not giving the greatest efficiency. For these reasons, together with the fact that so many new buildings have been erected recently, and that more will be constructed as the University grows, the authorities have deemed it advisable to install this most modern and complete heating and lighting plant.

ADDRESSES UNKNOWN.

An effort is made to keep on file the latest addresses of all the graduates. The mutual advantages of a complete list is obvious. Those who can assist us by giving information regarding the whereabouts of any of the following men will confer a great favor by so doing:—

J. R. Allen, '92; A. G. Anderson, '92; A. P. Augustine, '07. C. B. Aylesworth, '05; H. P. Barker, '93; H. E. Beatty, '04; M. B; Bonnell, '04; W. M. Brodie, '95; D. B. Brown, '88; J. M. Brown, '02; J. A. Brown, '07; W. J. Bruce, '07; R. J. Burley, '04; A. R. Campbell, '02; B. Carrey, '99; J. Clark, '00; G. A. Clothier, '99; P. C. Coates, '04; F. T. Conlon, '02; F. Dowling, '05; H. P. Elliott, '96; J. C. Elliott, '99; W. E. Foreman, '99; R. E. George, '03; A. C. Goodwin, '02; J. B. Goodwin, '92; W. A. Gourlay, '03; W. H. Greene, '09; R. C. Harris, '06; E. E. Henderson, '85; J. A. Horton, '03; H. S. Hull, '95; D. Jeffrey, '82; J. C. Johnston, '00; G. S. Jones, '05; W. C. Kirkland, '84; J. E. Lavrock, '98; A. E. Lott, '87; F. R. MacDonald, '08; J. M. MacInnes, '06; J. T. MacKay, '02; J. A. MacKenzie, '06; W. D. MacKenzie, '07; C. McCuaig, '04; G. G. McEwen, '04; D. W. McKenzie, '05; J. V. McNab, '06; F. W. McNaughton, '98; F. W. McNeill, '07; A. L. McTaggart, '94; F. Martin, '87; C. A. Maus, '03; R. S. Mennie, '02; W. Mines, '93; E. E. Moore, '04; R. W. Morley, '04; D. G. Munro, '07; J. D. Murray, '07; G. Pace, '04; J. D. Pace, '03; J. Paris, '04; H. A. Ricker, '08; H. D. Robertson, '02; W. A. Robinson, '08; J. O. Roddick, '06; A. E. Shipley, '98; R. W. Smiley, '97; S. E. Thomson, '04; E. A. Weldon, '97; A. F. Wilson, '07; J. N. Wilson, '06.

BOOK REVIEWS.

(We publish below a review of two books of which Mr. H. G. Tyrrell, a graduate of 1886, is the author, and in the case of the first, the publisher as well. Mr. Tyrrell's wide experience as a structural engineer fits him for such a task as the publication of these books imply. We hope to have him favor us with an address to the Engineering Society at some time during the year.)

History of Bridge Engineering. Henry Gratton Tyrrell, C.E.; published by the author, Chicago; 447 pages, 6x9, fully illustrated.

As pointed out in the preface, proficiency in any art is not attained until its history is known. Many students and designers have found, after weary hours of thought, that the problem before them was considered and perhaps mastered by others years ago.

Mr. Tyrrell has undertaken a stupendous task, as anyone who is at all familiar with the history of bridge building can readily attest. In view of this very fact, it is acknowledged by the writer that a great deal of information was necessarily crowded out of a volume of this size; but the final result is such that a very complete work has been gotten together. In the evolving of new work the designer does well to be familiar with outlines and details of other and perhaps older work. This book can very well help in giving such ideas to the designer.

Quite necessarily a good deal of space has been devoted to bridges built before the advent of metal as a structural material. Although professedly not of a technical nature, this book has distributed throughout its pages a large amount of dimensions that are valuable when taken in conjunction with the illustrations.

Altogether, the book is a credit to the author and will be a valuable addition to engineering literature.

Design and Construction of Mill Buildings. Henry Gratton Tyrrell, C.E.; published by the Myron C. Clark Publishing Co., Chicago and New York; 490 pp.; 6x9, fully illustrated; price $4.

Mill building construction is becoming an extensive branch of engineering in itself, and this book is a decided addition to the available literature on the subject. This book is the outcome of a smaller one entitled "Mill Building Construction," published in 1900. These books are based on the author's personal experience, and most of their contents are from his notes and records.

The author has included a part on "The Theory of Economic Design," which gives a knowledge of the possibilities and requirements. This has caused some repetition later in the book.

He has devoted a great part of the book to descriptions of the details and materials of construction. The different loads which may come on a structure are well analyzed, and there is a good chapter on framing.

There is a total absence, however, of methods of the theoretic analysis and graphic statics, which the author says have been sacrificed for more important material. His strictures on mathematics and mathematical analyses, in which he quotes Tautwine's Engineer's Handbook, might well have been omitted for the book lacks in just that department.

However, the book on the whole is a valuable one to the designer and estimator, containing much of use to both, when used in connection with other treatises on mathematical methods and statics.

THE ENGINEERING SOCIETY.

The University of Toronto Engineering Society held its first meeting of the year on October 18th. Dean Galbraith was the speaker, and gave an account of the history of the institution of which he is the head, since the registration of its first student. The address was exceptionally interesting to junior undergraduates, and was no less heartily received by those who had learned more or less of the "School" in previous years.

Several vacancies upon the executive of the society necessitated a call for candidates. Mr. R. J. Fuller, '11, was chosen by acclamation to succeed Mr. Watts as first vice-president of the society. The elections following other nominations resulted in Mr. R. D. Galbraith being elected to the presidency of the first year and their representative to the executive; while Mr. L. G. Glass was made first year representative to the undergraduates' parliament.

On Wednesday, Nov. 1st, Mr. E. H. Darling, '98, assistant engineer, Hamilton Bridge Works, read a lengthy and instructive paper on the design of manufacturing buildings. Mr. Darling's wide experience in work of this nature showed itself in his manner of dealing with such a complex subject so that students of all years were able to grasp the features under discussion. The paper appears elsewhere in this issue.

Mr. W. B. McPherson, '11, the president of the society for the year 1911-12, was in the chair.

The various sections into which the society is divided have made arrangements with a number of manufacturing establishments for official visits to their factories and plants in operation. Several of these little trips have already been made. On Oct. 19th over one hundred members of the civil section of the society visited the plant of the Canada Foundry Co. in this city, and spent a couple of instructive hours studying the different processes in operation there.

The various methods of manufacture, and the different machines were explained by Professors McGowan and Gillespie, Mr. Young, and other members of the staff.

The bridge department proved of special interest, considerable time being spent viewing the assembling of a bascule truss, and also the manufacture of different sizes of moulds for water pipes.

The wide range open for the inspection by a large party made this expedition a most successful one, and the Canada Foundry Co. are the recipients of high appreciation from the society for their courtesy.

On Oct. 25th about one hundred and fifty men of the third and fourth years, under the direction of Prof. Angus, went to Niagara Falls to inspect several places of interest there. The party first proceeded to the Ontario Power Company, where the intake system, power house and transforming house were visited. The plant of the Canadian Niagara Power Co. was also thoroughly inspected. The turbines here are arranged on a vertical shaft, the head being from 135 to 140 feet, varying with river conditions.

From this plant the party went up to the power house of the Toronto Power Co., where, as at the other two plants, the management were most courteous and obliging and afforded every facility for inspecting the plant. Here the erection of some new wheels was in progress, and it was an excellent opportunity for seeing the different parts of the turbines. Later a visit was also made to their transformer station on the hill.

WHAT THE GRADUATES ARE DOING.

(This department is conducted with double object in view; first, to give the graduates professional news of each other; second, to give the undergraduate readers some idea of the work in which they will be engaged after graduation).

E. T. Austin, '09, is with the Mond Nickel Co., Victoria Mines, Ontario.

H. H. Betts, '06, is in the employ of the Rio de Janeiro Tramway Light & Power Co., Rio de Janeiro, Brazil.

R. H. H. Blackwell, '10, is resident engineer for the C.N.O. at Biscotasing, Ont.

E. R. Birchard, '09, is with the Russell Motor Car Co., West Toronto.

E. T. Cain, '11, is in the employ of the Dominion Bridge Co., Lachine, Que.

A. Cameron, '06, is in the employ of the Vulcan Iron Works, Winnipeg, Man.

A. M. Carroll, '08, is with the Rochester Cobalt Mines, Limited, Cobalt, Ont.

N. L. R. Crosby, '05, is on construction work for the McClintic Marshal Construction Co., Chicago.

E. M. Dann, '09, is in the Railway Lands Branch, Department of the Interior, Ottawa.

G. W. Dickson, '00, is with the Laurentide Paper Co., Grand Mere, P.Q.

V. H. Emery, '10, is assistant manager of the McIntyre Mines, Porcupine, Ont.

R. H. Houston, '06, is with the Vulcan Iron Works, Winnipeg, Man.

A. E. Hunter, '09, is on survey work in the Peace River district.

J. T. Johnston, '08, is assistant engineer in the Trent Canal.

A. E. Lennox,'09, is publicity engineer for the N.E.L.A., Cleveland.

A. G. MacKay, '07, is in the employ of the Hudson & Manhattan Railway Co., New York City.

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ELECTROCHEMICAL AND ELECTROMETALLURGICAL DEVELOPMENTS IN CANADA.

S. DUSHMAN, B.A., Ph.D.

Part II.

The first part of this paper dealt with the present condition of electrochemical and electrometallurgical industries in this country. The list of plants in actual operation is not very imposing. That, however, this country is only at the threshold of an immense electrochemical development must be evident to even the least observant. The factors which up to the present have combined to retard the industrial progress of the country —"sparse population, great natural obstacles to transportation, peculiarities of geography, and our proximity to the more wealthy country to the south"—all these factors are either removed or else neutralized so as to exert little or no effect. The rapid growth in population, combined with the discovery of enormous natural resources, must lead to an unprecedented industrial development, and, considering the abundant water-power facilities of the country, the greatest developments must take place in the application of electrochemical and electrometallurgical processes.

In considering the question of the location of an electrochemical industry a number of factors have to be taken into account. There is, first of all, the problem of raw materials, secondly that of power, and thirdly that of transportation facilities. Other problems must undoubtedly occur in different cases, but in general the above are the main factors upon which the question of the location of an electrochemical industry depends.

The discussion of the possibilities which Canada offers from an electrochemical point of view must, therefore, fall under the following three headings:

I. Mineral Resources.
II. Water-Power Resources.
III. Transportation Facilities.

In attempting to discuss these questions on this occasion I do so with the full knowledge that they involve not only electrochemical but also purely economical and even political considerations, in all of which few are capable of expressing expert opinion. What has, indeed, stimulated me to attempt a discussion of such a complex subject on this occasion, is not the feeling that I can cast a sort of inspired light upon the problems involved, but the fact that this is the first occasion on which a distinctly Canadian city has been honored by a meeting of the American Electrochemical Society, and it is only fitting that on such an occasion attention should be drawn to the possibilities which we believe this country offers of exploitation by the electrochemist and metallurgist.

I. Mineral Resources.

The following remarks, based on the reports of the Conservation Commission, give a general idea of the mineral resources of Canada: "It will be noted from a mineral map that the greater portion of the country is as yet unprospected; about one-third lies within the prospected area and two-thirds without, and that the mineral resources have been developed (leaving out the Yukon) practically only in the territory lying fairly near the southern boundary. Even the portions of the country represented as being within the prospected territory must not be considered more than partially explored for minerals, as new discoveries are continuously being made within the supposed prospected areas. This has been the case at Cobalt, with the iron ore deposits of the Mattagami, and with the coal at Yellowhead Pass. It will, therefore, readily be seen that the unprospected area is very great, and, considering that much of the northern area has the same promising geological formation as some of our known developed deposits, it is reasonable to suppose that our mineral product will be greatly increased in its development."[1] In fact, wherever prospecting has been done farther north indications of valuable minerals have been found, and, by accident, great wealth has been uncovered in some cases.[2] It is not at all an exaggeration to state that nine-tenths of Canada's mineral regions are not yet explored.

At the present time the mining industry of the country is second only to agriculture. Its growth has been very rapid. In 1886 the total mineral production was slightly over $10,000,000; in 1909 it had grown to $92,000,000, and in 1910 to $105,000,000. In other words, the increase in 1910, as compared with the previous year, is greater than the total production twenty-five years ago. Of this total, slightly less than half consisted of metallic products. The statistics of the individual products are given in Table I.

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(1) C.M., p. 406.
(2) C.I., p. 9.

TABLE I.

The Mineral Production of Canada in 1910.[3]

Metallic.

Product.	Quantity.	Value.
Silver (ozs.)	31,983,328	$17,106,604
Nickel (lbs.)	37,271,033	11,181,310
Copper (lbs.)	56,598,074	7,209,463
Gold		10,224,910
Pig iron from Canadian ore (tons)	104,906	1,651,321
Iron ore (exports) (tons)	114,449	324,186
Lead (lbs)	32,987,508	1,237,032
Zinc ore and other products		235,000
Total		$49,169,826

Metallic.

Coal (tons	12,796,512	$29,811,750
Asbestos (tons)	75,678	2,458,929
Asbestic (tons)	24,707	17,629
Natural gas		1,312,614
Gypsum (tons)	513,313	939,838
Salt (tons)	84,092	409,624
Petroleum (bbls.)	315,895	388,550
Corundum (tons)	1,870	198,680
Other non-metallic products		1,100,664
Total		$36,438,278
Structural materials and clay products		19,432,854
Total mineral production		$105,040,958

When compared with other countries it is seen that Canada ranks well among the mineral producing countries of the world. In 1908 it stood first in asbestos, first in nickel, third in chromite, third in silver, seventh in copper, eighth in gold, and tenth in coal.[4]

The per capita production has increased from $2.23, in 1886, to $12.82, in 1909.[5] This compares favorably with the per capita production of approximately $17.00 in the United States. It is more than likely that in the next few years Canada will approach the latter figure much better.

The bulk of the mineral production of the country is at present derived from three provinces. In 1910 the proportion of the total output produced by each of these provinces was as

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(3) These statistics are take from the Preliminary Report on the Mineral Production of Canada, 1910, and are subject to revision.

The total pig iron produced was 800,787 tons, but from this has been deducted 695,891 tons, which was credited to imported ores.

The lead production was about 13,000,000 lbs. less than in the previous year, which "was due largely to the curtailment of production by several of the important Slocan mines consequent to the destruction of railway facilities and of several mine buildings by forest fires."

(4) C.M., p. 406.

(5) R. 88, p. 9.

follows: Ontario, 40.95 per cent.; British Columbia, 23.37 per cent.; and Nova Scotia, 13.38 per cent.

In the following sections different mineral resources have been treated at greater length. For a great deal of the information I am indebted to the splendid report on minerals issued by the Conservation Commission of Canada during the past summer. I have also made free use of the various bulletins issued by the Department of Mines at Ottawa. These form a veritable mine of information on Canada's resources.

Gold.—The gold production of Canada is mainly derived from the Yukon and British Columbia. The exhaustion of the richer gravels of the Yukon has led to a diminished but much steadier exploitation of the placer deposits. The production from this territory in 1910 was $4,550,000. "The future production will probably increase annually, owing to the mining being put on a more stable basis, due to the reduction of costs and the advent of large companies. Large companies are carrying on extensive operations for dredging and hydraulic mining for the purpose of working over the old tailings and large deposits of low-grade gravel."[6]

The gold production of British Columbia was $5,432,000, in 1910, most of it being from auriferous copper pyrites ores in the Nelson and Rossland districts. It is a question whether electrolytic methods of treating these ores would not be found to be more economical than the present metallurgical methods. In the treatment of the auriferous gravels of the placer deposits it is very likely that some process of electrolytic amalgamation might also be found to yield better results than the ordinary amalgamation methods. The remarks of E. E. Carey[7] are worth while quoting in this connection.

"In the near future we may look for a greatly increased production of gold, due to the application of electrochemical methods in mining and milling operations. Were electro-amalgamation and electro-cyanidation to-day in general use in other mills now in operation, the gross output of gold would be increased twenty-five per cent. The great increase in the future supply of gold, however, will come from vast low-grade deposits and ledges, which cannot now be economically mined."

That the gold resources of the Yukon and British Columbia have only been skimmed, as it were, is evident from the fact that the mountain ranges of this territory in which gold deposits have been found so far form the northern extremity of the "western or Cordilleran belt, which, extending from South America to Alaska, is recognized as one of the greatest mining regions of the world, noted principally for its wealth in gold, silver, copper, and lead." In both Mexico and the United States this moun-

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(6) C.M., p. 408.

(7) The Electrolytic System of Amalgamating Gold Ores. Trans. Am. Electrochem. Soc., 19, 127 (1911).

tain range has yielded about $3,000,000 per mile of its length, and it is only reasonable to expect that Canada, which possesses over 1,300 miles of this range, will yield enormous amounts of the precious metals in the future. The resources of placer gold in the Klondike alone have been estimated at $100,000,000. Up to the present probably not one twentieth of this vast area has been prospected in detail.

Silver.—About 90 per cent. of the silver produced in Canada in 1910 was derived from the rich silver deposits of Cobalt, Ontario, the rest being derived from British Columbia. Since the discovery of the Cobalt deposits, in 1904, the production of Canada has grown rapidly; in 1910 this country produced 32,000,000 ozs., or 13.3 per cent of the world's total production.

Fine silver is produced only at Trail, B.C., as a by-product in the lead refining process. "In Ontario ores from the Cobalt district are at present being treated at three metallurgical works operated by the following companies:

The Canadian Copper Co., at Copper Cliff, Ont.
The Deloro Mining and Reduction Co., at Deloro, Ont.
The Coniagas Reduction Co., at Thorold, Ont.

"Silver bullion of fineness varying from 850 to 998.2 is produced at the works, other products being white arsenic, and in the case of the Coniagas plant, nickel and cobalt oxides. In each case residues carrying silver, arsenic, cobalt and nickel are either shipped to the United States or held in reserve for further refining. In 1909 about 52 per cent of the total silver production was recovered in Canada as fine metal or bullion."[8]

The ores of the Cobalt district are extremely complex, and the problem of treating these ores economically is still awaiting a solution. Under present conditions one of the pressing needs for the further promoting of mining and metallurgical activity in northern Ontario is the devising of suitable methods for the treatment of the Cobalt silver ores. Only about thirty per cent. of the ore shipped from Cobalt in 1909 was treated in metallurgical works in Canada, most of this being high-grade silver ores, and the rest was shipped to a number of large companies operating in the United States. "With respect to the content of nickel, cobalt and arsenic in the ores, the mining companies are paid only for a small portion of the cobalt content, and nothing for the nickel and arsenic; in fact, in certain cases, the latter two are penalized."[9]

Another interesting problem in connection with the cobalt silver ores, is what to do with the cobalt. The situation is described in the report of the Bureau of Mines of Ontario for 1910, as follows:

"The cobaltic oxide trade is at present demoralized, and is likely to remain in this condition until a greatly increased use

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(8) R. 88, p. 107.
(9) R. 88, p. 109.

of the article enables the demand to overtake the supply. The enforced production of cobalt ore from the mines of Cobalt has resulted in a much greater quantity of ore than can be converted into oxide and marketed as such. In fact, one year's operation of the Cobalt mines will produce ore enough to meet the present consumption of oxide for several years. The inevitable consequence has been a very decided fall in the price of cobaltic oxide. . . . . . Cobalt ore cannot at present be sold, and none is being raised from any of the silver-free veins of the Cobalt camp, the entire production being of ore associated with silver. . . . The only hope of absorbing the cobalt contents of the ores which will continue to be produced in Ontario is in an enlarged demand, brought about either by the low levels to which the prices have fallen, or by new uses for the product. It is not unreasonable to expect that the former will lead to the latter."[10]

In the solution of these problems there is undoubtedly a field for the electrochemist and electrometallurgist. Not only is there an abundance of mineral wealth in the Cobalt region itself, but even in the districts farther north deposits of the most varied nature have been unearthed. Iron, copper, molybdenum, silver, gold, and even small diamonds have been discovered in the lone land south of Hudson's Bay. The whole of the Temiskaming region appears to be a vast mineral deposit where the richest ores and minerals of the earth have been thrown together in the past ages, in a most haphazard and extraordinary manner, so that one knows not what to expect in the future. Added to this is the fact that there are abundant waterfalls throughout the whole region. The facilities for transportation are being increased as fast as the country demands them; the government of Ontario has constructed a direct line to open up the agricultural and mining districts of the north of the province and is operating it by a commission. All these considerations serve to emphasize the fact that the hopes which are entertained for the electrochemical future of northern Ontario are not without some warrant.

Copper.—The copper production of Canada is derived from the provinces of British Columbia and Ontario. The production for 1910 from the first named province was about 36,000,000 lbs., most of this being derived from the Boundary district. The ores carry a low content of copper metal, but the smallness of the copper content is more than compensated by the fact that the probable reserves of metal in the province are enormous.

In Ontario there are many deposits of copper around the north shore of Georgian Bay. Some of these are being developed gradually. The great difficulty in the development of these deposits is the lack of a smelter, as the miners experience difficulty in marketing their ore under present conditions of trans-

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(10) B.M.O., p. 24.

portation.[11] It may be noted that similar conditions obtain with regard to the exploitation of the copper deposits of the province of Quebec.[12] The copper production of Ontario is, however, mainly derived from the nickel copper ores of Sudbury, which are discussed in the next section.

Of interest to the electrochemist is the fact that "no refined copper is produced in Canada, but the copper ores are mostly reduced to a matte or blister, carrying values in the precious metals,"[13] which is then exported. In 1910 the total exports of copper contained in ore, matte, and blister, according to Customs Department returns, were 56,964,127 lbs., valued at $5,840,553 (practically the whole of the production), and imported in the same year 30,237,106 pounds, mostly in the form of copper bar, strip, rod and plate. As was noted in a previous paragraph, the production of British Columbia alone was about 36 million pounds.

Considering the facilities for the development of hydro-electric power in the latter province, it is surprising, at first glance, that no copper refining plant has as yet been established in the Boundary district, especially when it has been found possible to operate a lead refining plant on a paying basis. To refine 30,000,000 pounds per annum would require a plant with an approximate capacity of fifty tons per day—no mean size, when it is remembered that the Balbach refining plant had this capacity in 1903 and was utilizing 750 h.p.[14] There seems to be no other reason for this state of affairs than the fact that, as the history of copper refining in the United States has shown, there has never been any general tendency to establish refineries near the mines. With very few exceptions, "the refineries from the earliest times have been established in the market centres of the East. They stand between the producer of crude metal and the consumer, and experience has shown that they are best placed at a distributing point for the territory of consumption which they are to serve."[15]

Nickel.—The discovery of the copper-nickel ores in the Sudbury district has placed Ontario in the position of being the largest producer of nickel in the world. These deposits now supply over 75 per cent of the world's total production of nickel. The main producers at present are the Mond Nickel Co., at Victoria Mines, and the Canadian Copper Co., at Copper Cliff. The former is an English and the latter an American company. The ore is first roasted and then smelted and converted into a bessemer matte, containing about 45 per cent. nickel and 35 per cent. copper. The total production of this matte in 1910 was 35,033 tons, containing 19,259,016 pounds copper and 37,271,033 pounds

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(11) R. 24, p. 313.
(12) Summary Report of the Mines Branch, 1909, pp. 69-74.
(13) R. 102, p. 10.
(14) T. Ulke, Trans. Am. Electrochem. Soc., 3, 224 (1903).
(15) Ingalls, Lead and Zinc in the United States, p. 78.

nickel.[16] The whole of this matte was exported to the smelting works of the two companies in England and the United States, while Canada imported over $23,000 worth of nickel and nickel anodes.[17] As Dr. Haanel has expressed it:[18] "We mine the ore, smelt it into matte, and send it as such out of the country. If we want nickel or nickel steel we have to import it. . . . Not only are these deposits of little material value to the country at present as exploited, but the method practised is exceedingly wasteful." Dr. Haanel has, in the same connection, indicated one method by which the ores might be treated so as to prevent this wholesale exportation. His scheme in brief consists in magnetic separation of the iron and magnetic nickel from the copper, precious metals and non-magnetic nickel compounds, followed by electric smelting of the iron-nickel portion to form ferro-nickel and electrolytic treatment of the tailings, as is practised at present in dealing with the matte. "The introduction of such a process, which would treat tailings containing the copper and part of the nickel by the electrolytic process in operation at Fredericktown, Missouri, and patented by Mr. N. V. Hybinette, would be in the interests of economy. A refiner, established in the Sudbury region on the plan outlined, would enable Canada to export finished products instead of the matte, as is now done."

Nickel also occurs associated with iron and sulphur as pyrrhotite, the percentage of iron averaging about 60 when the ore is pure. The experiments conducted under the direction of the Department of Mines, at Sault Ste. Marie, have demonstrated that a good ferro nickel pig can be produced from the smelting of roasted pyrrhotite by the electro-thermic process.[19]

Iron.—In discussing the iron ore resources of the country and their probable exploitation by means of electro-thermic processes, I am well aware that the subject has been abundantly discussed within the last few years. The facts which have been established are as follows:

1. Canada has immense iron ore deposits distributed at widely different points, as illustrated by the accompanying map. The deposits in Northern Ontario, in the Ottawa and Gatineau districts, and in Vancouver and Texada Islands are specially noteworthy.

2. Many of these ore deposits are situated in localities where coke for smelting operations has to be imported from Pennsylvania at prohibitive costs. In fact, it is only in the extreme eastern portion of Canada, where the iron ore of Newfoundland can be worked economically with the coal deposits of Cape Breton, that an extensive iron industry has developed. In On-

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(16) R. 102, p. 11.

(17) See R. 24, pp. 383-93, for a description of plants and metallurgical processes for the production of the matte.

(18) C.I., p. 68.

(19) R. 16, pp. 93-5.

tario and British Columbia coke for metallurgical purposes has to be imported.

3. The deposits are, however, usually situated near some source of water-power that could be developed at low cost.

4. The experiments at Sault Ste. Marie have shown that by the electro-thermic process it is possible to smelt economically not only hematite ore, but also magnetite ores, which are the chief source of iron in this country. Furthermore, owing to the high temperature at which the reactions occur in the furnace and the consequent possibility of fusing highly basic slags, ores high in sulphur as well as titaniferous ores can be readily reduced in the electric furnace. The experiments also showed that in place of the expensive coke derived from Pennsylvania, peat coke as well as mill refuse and sawdust can be used.

While these facts have led to very optimistic views on the possibilities of developing a large Canadian iron industry by the use of electro-thermic processes, other considerations have also led investors to be rather conservative of embarking on ventures in this direction.

The most prominent fact about the iron and steel industry of the United States is its magnitude. The necessity for economy in even the smallest detail has led to colossal aggregations, in which every process has been devised by the most expert minds and carried out with the most improved machinery. To develop an industry in Canada which shall compete, for even the Canadian market, with the output of such plants, must require not only "a heavy initial expenditure in prospecting, securing and developing mines, timber lands, limestone quarries, railways, shipping docks, etc., necessary to secure a constant supply of the raw material," but also an extremely heavy outlay in the establishment of the plant itself, "an outlay which is much heavier in proportion to output than is required for the production of any other article of commerce."

Outside of the heavy investment necessary for economical running the nature and extent of the ore deposit itself is of prime importance. Before any development whatever can be considered, there must be a certainty that the deposit of ore is not only extensive but also suitable for metallurgical purposes. The lack of ores suitable for treatment by the blast furnace has, in fact, been one of the factors preventing the growth of an iron industry in Ontario. In this province there were smelted, during 1909, 543,000 tons of foreign (United States) ores, while 220,000 tons of domestic ores were treated.[20] Under the present conditions, the Ontario smelters have to pay a maximum figure for fuel, and are therefore naturally anxious to smelt only "those ores that yield an amount of merchantable pig iron sufficient to insure the operation of the furnace upon a profitable basis. If the smelter could secure a cheaper fuel, he could afford to smelt

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(20) B.M.O., pp. 29-30, also p. 154.

leaner ores, but so long as he must pay between five and six dollars a ton for his coke, furnace economy requires an ore mixture yielding a maximum percentage of iron."

By the use of electro-thermic processes and some method of concentrating the ores, it is quite within the limits of possibility that a much larger iron industry could be developed in Ontario. Recent government experiments on low grade magnetite ores from different points in Ontario have demonstrated "that first class bessemer concentrates (with one exception) can be produced from the crude ores submitted for testing purposes, and it has been shown that all of these concentrates will form hard porous briquettes, more or less peroxidized and free from sulphur, when submitted to a process similar to the Grondal system of briquetting."[21] These briquettes could, of course, be treated in the electric furnace, thus cutting down on the necessity for using a high-priced fuel. The combination of concentration and electric furnace appears all the more advantageous when it is considered that Ontario contains numerous sources of power that could be developed at low cost.

Another factor which has so far hindered the development of iron smelting plants in certain localities is the lack of a sufficient market near at hand. An excellent illustration of this is furnished by the case of Vancouver and Texada Islands. These islands have abundant supplies of magnetite ore; the numerous inlets off the coast enable transportation costs to be reduced to a minimum,[22] but at the present time no iron ore is mined for two very good reasons—lack of cheap metallurgical coke and absence of a market close at hand.

In the electric furnace it would probably be possible to utilize the coal from Vancouver Island, of which there is an abundant supply. In a recent report on the iron ores of this region, Mr. Lindeman estimates that pig iron could be produced on the coast at about $16.00 per gross ton, as compared with a present cost to consumers of $22.00 to $31.00. "It would therefore appear," he writes, "that an iron industry on the coast of British Columbia should be fairly remunerative, provided that the province has a sufficient market to support such an industry. This is, however, not the case at present, the import of pig iron during the fiscal year ending March, 1908, being only 2,282 short tons.

"With such a limited home market, an iron industry would have to find a market for its surplus product outside the province. A large and growing market is certainly offered by the western United States, but the manufacturers of that country are protected by a customs duty of $4 per ton of pig iron. The rapid development of the western States seems to suggest that an iron industry on the Pacific coast of the United States, will

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(21) B.M.O., p. 171.
(22) B.C., p. 24.

soon be established.[23] That such an industry, protected by the high import duty of $4 per ton on pig iron would be a dangerous competitor with a British Columbia blast furnace plant, in this American market, is apparent. On the other hand, it has often been suggested that the Orient would offer a great market. This is a question of the future, but as conditions are now, it seems impossible that a British Columbia smelting furnace, working with expensive labor and fuel, could compete with other iron producers of the world in this Oriental market.

"Though a profitable iron industry does not at present seem probable, there is room for confident anticipation, that, with the prospective rapid development of the province, the conditions will be more favorable in the future, and that it will then be practicable to turn to profitable account the iron ore resources on the coast of British Columbia."[24]

For a number of years the Canadian Government has attempted to encourage the development of an iron and steel industry in this country by subsidizing the manufacture of both products.[25] More recently bounties have also been established on iron and steel manufactured by the electro-thermic process. So far, however, the iron industry has not kept pace with other metallurgical developments. The total output of pig iron during 1910 was 800,797 tons, valued at $11,245,630. The total production of steel ingots and castings in the same year was approximately 822,881 tons.[26] Considering the fact that during 1910 there were imported only 158,910 tons of pig iron,[27] it appears as if at the present time the production of the country is almost keeping pace with the demand. With the growth in population there must, however, come a rapid increase in the number of engineering projects throughout the whole country, and, consequently, a much greater demand for iron and steel. Considering the advantages offered by electro-thermic processes and their special applicability to Canadian ores, there seems to be no doubt but that there is a promising future for the electric iron and steel industry in this country.

Zinc.—The zinc resources of British Columbia are considerable. In 1905 the Canadian Government appointed a commission to investigate the zinc resources of the province. As the report of this commission[28] contains complete information upon this subject, only a brief summary of the situation need be given in this connection.

Zinc occurs in British Columbia mainly as blende associated

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(23) Since the above was written an electric iron plant has been established in California.

(24) Iron Ore Deposits of Vancouver and Texada Islands, p. 26.

(25) R. 24, pp. 310-11.

(26) R. 102, p. 13.

(27) Report of the Department of Trade and Commerce, 1910, pp. 48-9.

(28) See R. 12.

with argentiferous galena. While there are large deposits of fifty per cent. ores in the Slocan and Ainsworth mining districts,[29] there are also numerous deposits of ores which are poorer in zinc. "Until lately no account was taken at all of zinc contents in these ores, and a large amount of this very valuable metal was lost.[30] The attention of the Department of Mines has, however, been directed toward the problem of utilizing these ores commercially, and there is no doubt that in the near future some electrometallurgical process will be devised for recovering both the lead and zinc in these ores.

The question of treating the zinc ores of the Kootenay by some electric process has, indeed, received considerable attention during recent years. When it is remembered that the quantity of fuel required per ton of ore is greater in zinc smelting than in any other of the common metallurgical processes (about 1.75 tons of coal per ton of ore in the best practice),[31] it is readily seen that a process which substitutes power produced at low cost for a considerable portion of the expensive fuel, must appear desirable. It is worth noting that this factor of cost of coal influenced the Canada Metal Co., Ltd., to erect its smelter at Frank, Alberta, in the Crow's Nest Coal Field, just east of the British Columbia line.

In 1909 a Snyder zinc smelter was erected at Nelson, B.C., by the Canada Zinc Co. The intention was to treat mixed argentiferous zinc-lead ores, with a view to producing lead bullion and commercial spelter in one operation. So far, however, the plant has remained practically idle.

As already mentioned, the Department of Mines, at Ottawa, is interested in the problem of exploiting the ores of the Kootenay district, and an investigation is now being carried on by Dr. Stansfield, at McGill University, on characteristic ores of this district. According to the most recent information,[32] Dr. Haanel has announced "that if the preliminary research work indicated an electric process, the smelter built at Nelson by the Canada Zinc Company would almost certainly be used to complete the work, while, if some other process were indicated, the smelter would probably be located at Nelson in any event, for convenience to power and the ores."

The report from which the above is taken also contains the information that two private companies are conducting experiments with electric smelting of zinc ores of the Kootenay. It is, therefore, to be expected that some economical process will

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(29) According to the Report of the Commission, p. 47, "15,000 tons of ore of 50 per cent. grade would be a liberal estimate for the annual productive capacity of the Slocan." The mine of the Ainsworth camp could, according to the estimate of the Commission, produce 16,000 to 30,000 tons per annum.

(30) C.I., p. 10

(31) R. 12, p. 51.

(32) B.C., p. 103.

be devised in the near future for treating the zinc ores of British Columbia.

A rather interesting contribution to this subject has been made by Mr. Ingalls, in the report on the zinc resources of British Columbia,[33] to which reference has been made already. He writes as follows:

"It is unlikely that the electric smelting of zinc ore can ever be profitably carried on in the zinc producing districts of the East and West Kootenays, B.C., because in many parts of those districts the water-powers are small and irregular. . . . Where there are large water-powers, as for example, at Bonnington Falls, the power generated is so valuable for mining and miscellaneous purposes that it could not be furnished at the low figure which would be required by an electric smelting plant.

"On the coast of British Columbia, I am informed, there are many large water-powers, which can be developed at so comparatively small a cost as to permit them to furnish power at a low figure. It is possible that at some future date these may be utilized for the electric smelting of zinc and other ores. Possibly, also, water-powers in Eastern Canada may be similarly utilized. Any such development is, however, something of the future, and is not to be reckoned upon at the present time. Electric smelting of zinc ores must undoubtedly go through many stages of experiment before it can be pronounced a metallurgical and commercial success."

Coal.—The following table, taken from the report of the Conservation Commission,[34] gives some estimate of the coal resources of Canada:—

Province	Area of Coal Land (in square miles.)	Anthracite (in millions of tons.)	Bituminous (in millions of tons)	Lignite (in millions of tons.)	Total. (in millions of tons.)
Nova Scotia	992		6,250		6,250
New Brunswick	112		155		155
Manitoba	48			330	330
Saskatchewan	7,500			20,000	
Alberta	19,582	400	44,530	60,002	104,932
British Columbia ...	1,123	20	38,642	314	38,976
Yukon	400	32	32	850	914
Mackenzie Dist.	200			500	500

The coal of Nova Scotia, which is derived from the carboniferous formation, is bituminous, of good quality, well adapted to the production of coke, and excellent for domestic uses and for steam coal.

The most important coal areas of Canada are located in the western provinces, the coal being found in the Cretaceous formation. As shown in the table, these coals are mostly bituminous and lignite, the coke from which is not nearly as suitable for metallurgical purposes as Pennsylvania coke.

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(33) R. 12, pp. 129-33.
(34) C.M., p. 430.

A noteworthy feature is the total absence of coal areas in the provinces of Quebec and Ontario. As, however, the latter of these provinces possesses large peat bogs, the attention of the Department of Mines has been directed in recent years towards the question of utilizing this source of fuel, and very favorable results have been obtained.[35]

It may be that, as a result of the experiments performed at Sault Ste. Marie, it will be possible to utilize this peat in electrometallurgical industries. In that case, Ontario iron smelters would no longer be compelled to import coke from Pennsylvania.

Miscellaneous Industries.—While in the above paragraphs the probable electrometallurgical developments in this country have been the subject of discussion, it must not be forgotten that there are opportunities in Canada for the growth of other electrochemical industries.

During 1910 Canada imported 682,816 dollars worth of nitrate of soda and over a half-million dollars' worth of other fertilizers. It is more than likely that with the growth of the farming industry of the country there must come a time in the near future when there will be a much greater demand for artificial fertilizers, and "seeing that this country is almost prodigally furnished by nature with water powers, from which electric energy can be developed at reasonable rates, there is no reason why a flourishing industry in the manufacture of air nitrates (similar to that of Norway) should not be established for supplying not only our own home market, but also the markets of the United States and the Orient."[36]

The production of different ferro-alloys also seems to offer an inviting field. There are numerous deposits of tungsten, chromium and manganese ores throughout the eastern provinces, and there is no doubt that the exploitation of some of these deposits would be found a profitable venture.

Water-Power Facilities.

A discussion of the future electrochemical developments of Canada would be incomplete without some mention of its water-power facilities.

A complete survey of the total available water-power resources of this country has yet to be made. Such a summary is promised by the Conservation Commission. A very fair idea, however, of these resources may be obtained from the reports of the Hydro-Electric Commission of Ontario and from the address delivered by Mr. Coutlee, the engineer of the Ottawa Storage Company at the first annual meeting of the Conservation Commission.[37]

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(35) See Report No. 71, Department of Mines, Ottawa.
(36) Summary Report of the Mines Branch, 1909 ,p. 7.
(37) C.I., p. 152.

In the province of British Columbia the total amount of power already developed and in process of development amounts to about 75,000 horse-power. It is impossible to state what amount of power can be obtained from the numerous water-powers off the coast, but they would certainly aggregate another 50,000 horse-power.

The Mackenzie basin presents few power possibilities, but the basin of Lake Winnipeg, with a drainage area of 350,000 square miles, "promises well for water-power when an increasing population provides the demand." Lake Winnipeg itself is an enormous reservoir 700 feet above Hudson's Bay, and it flows out through the Nelson River, which has exceptional opportunities for water-power. The rivers which empty into Lake Winnipeg also offer opportunities for water-power.

In Ontario the sources of water-power are almost innumerable. Nearly every village and town which is anywhere near a water-power has developed its own municipal light and power plant and holds forth enticing offers to the manufacturer who will locate in its boundaries. A very complete summary of the water-power available from the different divisions has been given by the Hydro Electric Commission of Ontario. From their reports, it is probably safe to estimate that the total available water-power of the province, excluding that available from Niagara Falls and the Soo rapids, is close unto a million horse-power.[38] The Ottawa River alone is capable of supplying over 300,000 horse-power, while the numerous falls on the Gatineau can supply over 200,000 horse-power.

In the province of Quebec, "the numerous tributaries of the St. Lawrence present remarkable power possibilities, as they flow in rock basins with many abrupt falls." Montreal, Quebec, Three Rivers, and other cities along the St. Lawrence, are supplied with light and power by hydro-electric plants.

New Brunswick also possesses several rivers with exceptional power possibilities. "At the present time only the St. John River has been exploited. The Grand Forks Power Company is building a plant at that place to develop 80,000 horse-power. This will be used for the manufacture of pulp and for the municipal supplies of Woodstock, Fredericton and St. John."

This brief summary will probably serve to convey some idea of the numerous water-power facilities of this country. Canada is at present in the happy position of possessing in these water-powers a source of wealth which has not been monopolized to any extent, and in view of the policy adopted by the legislature of Ontario, as well as other provincial legislatures, it is certain that such a national heritage will be entrusted to the care of none but those who will utilize it for the people under terms to be defined by the people.

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(38) This estimate has been obtained by adding the figures given in the reports for the individual water-powers.

Transportation Facilities.

Next to the subject of power development that of transportation facilities is of greatest interest to the industrial chemist and metallurgist.

The history of railway development in Canada is one of the most remarkable features of Canadian history. When it is remembered that in the year of Confederation (1867) Canada possessed only 2,278 miles of railroad, while at the present time it indulges in the possession of a railroad mileage which is close unto 25,000; when it is remembered that the Canadian Pacific Railway was only completed in 1886, just twenty-five years ago, after the Government had granted the company 62 millions in cash and construction and 25 million acres of land, while at the present time there are in operation two more transcontinental railways; when these facts are considered well, it is apparent that the railway facilities of this country have been increased at an enormous rate during the past two decades. The various branches of these three great railways penetrate forests which five years ago had rarely felt the tread of a white man: the periodical arrival and departure of trains has become an unnoticed phenomenon in towns which have risen at the command of some modern Aladdin, as it were, in regions which not more than five years ago were as far removed from civilization as Toronto is from New York.

This completes, in a sense, the discussion of the possibilities in electrochemical and electrometallurgical possibilities which Canada offers. While time and space have necessarily forbidden me to dilate to any extent on any one topic, I trust that some idea at least has been conveyed of the faith which a great many individuals have in the future of this country.

We have crossed and re-crossed in magnificent leaps of 3,000 miles the vast region comprised under the name of the Dominion of Canada. From Ungava to the Yukon, from the smiling fruitland of the Niagara peninsula to the vast Cordilleran ranges, there stretches a country which possesses resources and wealth such as few can conceive.

This land, endowed with a mineral wealth beyond the wildest dreams of the present generation, this land, upon which has been bestowed in profusion all the advantages which go towards the forming of a great commercial nation, looks forward to the twentieth century as its very own. The nineteenth century has seen the growth of a wonderful nation in one-half of the North American continent, the twentieth century will see the equally remarkable rise of a twin-nation in the other half of this continent.

In this great evolution which must occur in the next decade, the electrochemical engineer will be called upon to solve many problems, not the least important of which will be that of utilizing the natural resources of this country in the most economical manner possible, and upon this task h will have to concentrate all his knowledge and wisest judgment. Let us hope then that he will not be found wanting at this great opportunity.

Abbreviations.

C.I.—First Annual Report of Commission of Conservation, Ottawa, 1910.

C.M.—Report of Commission of Conservation on Lands, Fisheries and Game, Minerals, Ottawa, 1911.

R. 12—Report of the Commission appointed to investigate the Zinc Resources of British Columbia and the Conditions affecting their Exploitation, W. R. Ingalls, 1905. Report No. 12, Department of Mines, Ottawa.

R. 16—Report on the Experiments made at Sault Ste. Marie, under Government auspices, in the smelting of Canadian ores by the electrothermic process. Report No. 16, Department of Mines, Ottawa.

R. 24—General Report on the Mining and Metallurgical Industries of Canada, 1907-8. Report No. 24, Department of Mines, Ottawa.

R. 88—Annual Report on the Mineral Production of Canada, 1909. Report No. 88, Department of Mines, Ottawa.

R. 102—Preliminary Report on the Mineral Production of Canada, 1910. Report No. 102, Department of Mines, Ottawa.

B.M.O.—Report of the Bureau of Mines, Ontario, 1910, Part I.

B.C.—Report of the Bureau of Mines, British Columbia, 1910.

STEAM CONDENSING EQUIPMENTS.*

A. G. CHRISTIE, '01.

Asst. Professor of Steam Engineering, University of Wisconsin.

It is a matter of general knowledge that the atmosphere surrounding the earth consists of a mixture of gases, principally of oxygen and nitrogen, and that this atmosphere extends to a sufficient height above the earth's surface to produce a pressure at sea level of 14.7 pounds per square inch absolute. For ordinary purposes of life this pressure is not objectionable, but in certain phases of engineering, especially when steam is used, this pressure is detrimental and steps have to be taken to reduce it. It is usually desired to make this reduction of pressure in a closed chamber, such as an engine or turbine cylinder. Such a reduction of pressure, in ordinary engineering terms, is known as "producing a vacuum." Hence we can define a vacuum as a reduction of the pressure in a chamber below that of the surrounding atmosphere.

The equipment to produce a vacuum in steam engines is known as the condensing outfit and consists of the condenser and its accompanying pumps.

The pressure of the atmosphere is usually measured on a barometer, which indicates this air pressure by the height in inches of a column of mercury. Hence 14.7 pounds per square inch absolute corresponds to a barometer of 29.97 inches of

*Read before the Engineering Society, Nov. 30, 1911.

mercury, which is usually spoken of as a 30-inch barometer. Now, if the air pressure in a closed chamber is reduced below that of the surrounding atmosphere, and if this chamber is connected to one end of a glass tube, the lower end of which is placed in a bath of mercury, then the atmosphere will force the mercury up the tube until the height of the mercury column equals the difference in pressure between the inside of the chamber and the atmosphere. Thus we have the common means of measuring vacuum by the height of a column of mercury in inches equal to the differences of pressure on the inside and outside of an engine exhaust. Hence one hears an engineer remark that he carries 28 inches of vacuum on his turbine exhaust.

One of the advantages to be gained by producing a vacuum in an engine exhaust is the increased energy made available by the expansion of the steam, and, consequently, the more useful work each pound of steam will produce in the engine. This can be shown very clearly in Fig. 1, which shows on a temperature entropy diagram the ideal or adiabatic expansion of one pound of dry steam from 150 pounds pressure above atmosphere to a pressure of 1 pound per square inch. Without entering into a discussion of the construction or meaning of this diagram, it will be sufficient to say that the area ABCD is proportional to the energy available for work when steam expands without external losses from 150 pounds per square inch above the atmosphere to atmospheric pressure. The area ADFE is proportional to the energy available for work when the expansion is carried further from atmospheric pressure to a pressure corresponding to a 26 in. vacuum, as is usual with a steam engine, while the area ADGH represents the corresponding energy with a 28 in. vacuum, as used on steam turbines. A glance will show that the energy available for work by expanding the steam from atmospheric pressure into a 28 in. vacuum is almost equal to the energy available by expanding the steam from 150 pounds per square inch to atmospheric pressure. It is, therefore, obvious that a suitable engine operating with 28 inches of vacuum should produce about twice as much work per pound of steam used as an engine with no vacuum at all, or, conversely, the former should use just half as much steam as the latter for the same work. A reduction in steam consumption brings about a corresponding reduction in the amount of coal burned, and hence a decrease in the cost of power.

All water used for commercial purposes contains a small amount of air in solution, usually taken as 5 p.c. When this water is pumped into a boiler it carries some air with it in solution. After it has been evaporated into steam, the mixture of air and vapor passes over to the engine and out the exhaust. If the expansion of steam is carried below atmospheric pressure to a vacuum at exhaust, there will be a tendency for the atmospheric pressure to force air in through stuffing boxes, packing, or any other possible opening. When air leaks into a vacuum in such a manner its volume is increased many times.

The exhaust from an engine is then a mixture of air and steam vapor, and, in order to maintain the vacuum desired, this must be at once removed. The steam may be converted into water again by removing its latent heat by means of some cooling medium, usually cold water from another source of supply. Hence we have arrangements in condensers whereby cold water is either brought into contact with the exhaust steam itself or is circulated on the inside of metal tubes, which are surrounded on the outside by the steam. These are the two fundamental types of condensers. The former is known as the jet condenser, while the latter is called the surface condenser. In jet condensers, the water is often forced into the vacuum of the condensing chamber by the pressure of the atmosphere. But for all other purposes a means must be provided to circulate the required amount of cooling water, and what is known as a circulating pump is usually used for this purpose.

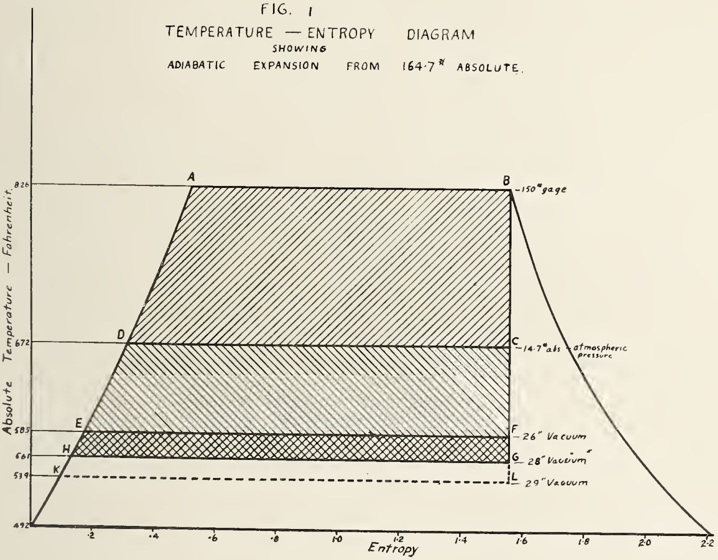


FIG. 1
TEMPERATURE — ENTROPY DIAGRAM
SHOWING
ADIABATIC EXPANSION FROM 164·7# ABSOLUTE.

The air, which has been carried along with the steam must also be removed if a vacuum is to be maintained in the condenser. It cannot be condensed, and hence must be pumped out by some means as fast as it enters. The form of air compressor used for this work is known as an air pump. Hence we have as our essentials to maintain a vacuum a condenser, its circulating pump and its air pump.

Referring again to Fig. 1, it would seem that the higher the vacuum the greater would be the energy available and the more efficient the engine would become in its use of steam. The limitations of the cylinder sizes and other factors in reciprocating engines are such that usually no further expansion is profitable beyond 26 inches of vacuum. But there is no limit in steam turbines to the vacuum which may be carried if the blading is suitably designed. Fig. 2 shows the decrease in steam consumption of a steam turbine as the vacuum increases, as found by actual test.

The cooling water leaving the condenser cannot be hotter than the steam temperature corresponding to the degree of vacuum, and, in many condensers, is usually 10°F. below this temperature. The temperature of steam with 26 inches vacuum is 125°F., with 28 inches vacuum 101°F., while with 29 inches of vacuum it is only 80°F. The corresponding outlet water temperatures allowing 10°F. drop as above would be 115°F., 91°F. and 70°F., respectively. If the average temperature of the water supply is 55°F., then each pound of cooling water will carry away 60 B.T.U., 36 B.T.U., and 15 B.T.U. in the three cases. The heat to be removed from the steam to condense it for approximation can be said to remain constant in all three cases, so that the quantity of cooling water to condense the same weight of steam in the three cases will be about as 1:1.66:4. As it takes power to pump this water, it can be seen at once why it costs more to maintain the higher vacuums.

FIG. 2

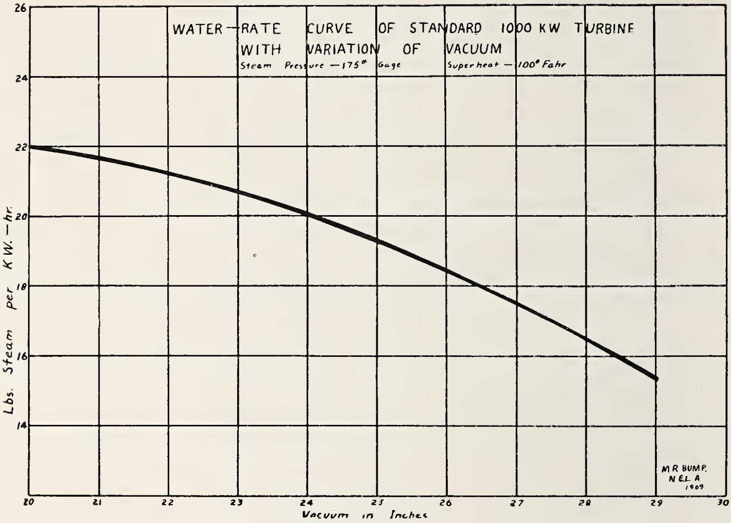


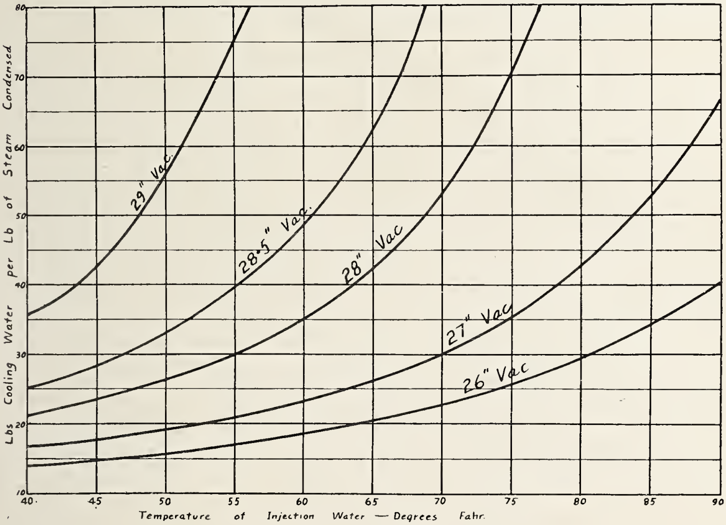
Fig. 3 shows the actual amount of circulating water required in practice for different vacua. For high vacuum there must be a much greater supply of cold water than for a low vacuum.

Now the volume of the air increases rapidly with the higher vacua and hence the volume of the pump cylinder must be increased to provide for it. More power will be required to compress this air to atmospheric pressure. Consequently an increase in vacuum means a corresponding increase in operation costs on the air pump.

The condensation problem then resolves itself into an equation of costs. If the water supply is limited, then the vacuum that may be carried will be fixed by this consideration. But if there is ample cold water, then one must determine when the saving in fuel costs, due to decreased steam consumption on the main engine, equals the increased operating costs of pumping cooling water and removing air together with the upkeep, interest and depreciation of this larger and more expensive apparatus. Usually the limiting factor is the amount of air leakage into the engine cylinder, the exhaust line, and the condenser, and every step should be taken to reduce this to a minimum.

FIG. 3.

CURVES SHOWING THEORETICAL COOLING WATER REQUIRED PER POUND OF STEAM CONDENSED. 10°F DIFF. BETWEEN DISCHARGE WATER AND VACUUM.



A treatment of the economics of such an engineering problem, while of very great practical interest, is beyond the limits of this discussion, and the remainder of the article will deal with present day commercial forms of condensing equipment.

Some engineers hold that it is not possible to maintain as relatively high a vacuum at a high altitude, like that of Calgary, Alberta, as near sea level. Now, the absolute pressure in a condenser is equal to the difference between the vacuum and the barometric pressure, and this can be maintained constantly irrespective of altitude with any given equipment. Moreover, it can be shown that not only is it possible to hold as good an absolute vacuum at the high level, but the power to drive auxiliaries is decreased to a considerable extent at the same time. Hence the cost of producing the same relative vacuum remains constant or decreases slightly as the altitude increases.

The essential requirements of a condensing plant may be stated as follows: Sufficient cooling water must be supplied to provide the necessary vacuum; there must be a rapid transfer of heat from the steam to the cooling water in order to produce quick condensation; and the accompanying air must be removed with the least expenditure of power.

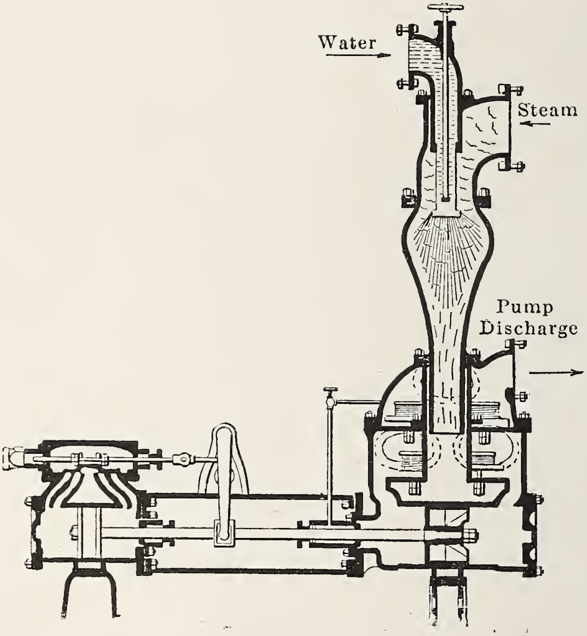


Fig. 4
Jet Condenser.

In commercial practice there are three simple types of condenser used to provide vacua up to 26 inches, such as are required in steam engine work.

The simplest of these is the ordinary jet condenser shown in Fig. 4. This consists of a vacuum chamber, in which the cooling water and steam are brought into intimate contact, and after condensation all water and the accompanying air are removed by a piston pump attached to the bottom of the condenser. In the usual designs of this type there is seldom an intimate mixture of water and steam, and hence more water is required than should be necessary. But even under these conditions the amount of cooling water is often much less than that required by ordinary surface condensers. The equipment is cheap in first cost and occupies very little space. As the cooling water carries air in solution, air pumps of large capacity are required with consequent large power expenditure. There is also the disadvantage that the condenser discharge cannot be used to feed boilers unless the cooling water is unusually pure and free from acids or alkalis. Unless care is taken in operation there is also the possibility of water being drawn over into the low pressure cylinder of the engine should the load go off suddenly. Such an occurrence usually wrecks the engine. Improvements, which will be referred to later, have recently been made on this type to adapt it to the requirements of high vacuum work, so that it is still one of the most important types of condensers.

The barometric condenser is a modification of the simple jet. The cooling water and steam are led in separate pipes to an elevated condenser head at least 34 feet above the level of the hotwell, where the two are mixed. The resulting mass of water all passes out through a tail pipe, which is submerged in the hot well. The air present in the condenser is entrained by various methods as the water leaves the head, and is thus carried away at the same time. This condenser arrangement costs more than the simple jet to install, but is very cheap to operate. If near the cooling water supply the head to be lifted against by the circulating pump is equal only to the difference between the height from supply level to condenser head and the equivalent head of vacuum. A vacuum of 26 inches can be easily maintained in most condensers without an air pump. There is no possibility of flooding engine cylinders with this arrangement of piping. The condenser head can be so arranged that the mixing of water and steam is very intimate, and thus the least amount of water can be used to maintain a given vacuum. This type of condenser is especially adapted for using very foul water, and if the pump and condenser are lead lined, it can be even used with acid mine water.

A typical surface condenser for steam engine work is shown in Fig. 5. It consists of a closed vessel, usually of cast iron, of either circular or rectangular section, into which the exhaust steam is led. This chamber is traversed by a large number of thin brass tubes, through which water is circulated. The steam strikes these cold tubes, condenses, and falls to the bottom of the shell. The air being heavier than the steam, also collects in the bottom, and these together are removed by the wet air pump. This pump is driven by a small steam cylinder. The pump for circulating the cooling water is placed on the other end of the common piston rod. The cooling water and condensed steam do not mix, and hence the latter is pure distilled water, which can therefore be fed directly into the boilers, provided it is not rendered useless by the presence of too much cylinder oil. Water absolutely unfit for boiler feed may be used for cooling, and thus we find that in marine work the surface condenser is used almost exclusively. As there must necessarily be a difference in temperature between the cooling water and the steam in order that heat may flow through the metal tube, a greater amount of cooling water will be required with this type of condenser than with either of the preceding types. The first cost of this equipment is high and its repair charges are also high. Since the amount of air to be removed is relatively small as compared with the jet or barometric condenser, its air pump is also small, and hence its operating costs are low.

In surface condensers the cooling water is usually arranged to enter the lower tubes and leave from the upper tubes, so that each tube is filled with water irrespective of the amount circulated.

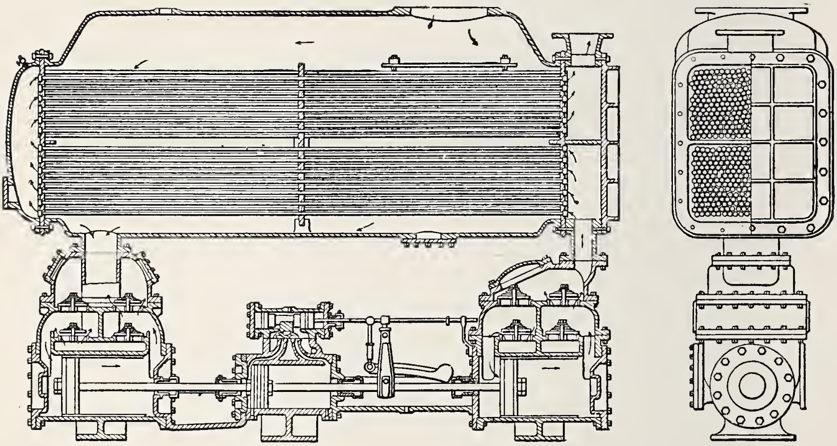


Fig. 5.

Surface Condenser.

The condensers dealt with so far have been those intended for use with reciprocating engines. At the present time, however, steam turbines are invariably installed for most purposes where the power exceeds 400 h.p. in one unit. In steam turbines, as already pointed out, the maintenance of high vacuum results in improved operating economy. Therefore the condensing equipment chosen for use with steam turbines should aim to provide the highest vacuum possible under the conditions of operation.

A number of considerations should enter into the selection of the type of condenser for high vacuum. The amount and average temperature of the cooling water may place limitations on the vacuum to be obtained. Its quality and its suitability for boiler feed purposes are factors which influence largely the selection of the type of condenser. It has been the experience of the writer that power plant designers very frequently overlook the adaptability of the water supply to boiler feed purposes. Barometric condensers have been installed where the water supply, on account of the scale-forming substances held in solution, was absolutely unfit for feeding into boilers. At other times surface condensers have been installed where the water was quite soft and where a cheaper equipment could have been easily justified. This is a very important consideration and should receive most careful attention, if the operating costs are not to be excessive.

To obtain high vacuum there must be sufficient cooling water for the type of condenser selected. This condenser must be of such construction as to provide a rapid transmission of heat from the steam to the cooling water. Air pumps are always used for high vacuum, and these must be of ample capacity to remove the mixture of air and water vapor, which is always present under these conditions. In order to make the capacity of this air pump as small as possible the air should be removed from the condenser at a point where it will be coldest, and hence occupies the least volume.

In the modern high vacuum surface condenser the cooling water is forced through the tubes at a high velocity, usually by a centrifugal pump, either motor or engine driven. The tubes are of brass and as thin as permissible for the service. These must frequently be cleaned of foreign material, which is carried in by the cooling water. The size of shell and the arrangement of tubes and baffling is such that the steam is directed against the tubes at a high velocity, thus insuring a very rapid transmission of heat and quick condensation. It has been noted that when the condensed steam from one tube is allowed to drip over all those below it, this film of water impairs the cooling qualities of each tube it passes over. Hence baffles are provided at intervals to carry the condensed steam to the sides of the shell. The circulating water, which makes three or more passes through the condenser, enters the bottom tubes first. Since the water in this portion is coldest, a certain number of tubes in the bottom are protected by a baffle from direct contact with the entering steam. The air is led through these tubes and cooled on its way to the pump suction.

Hon. C. A. Parsons introduced an additional feature shown in Fig. 6 to improve the efficiency of his surface condensers. It is known as a vacuum augmentor, and consists of a small steam jet placed in the throat of an ejector nozzle, which produces an additional vacuum to that of the pump and thus draws out the air from the main condenser and slightly compresses it. This mixed air and steam is passed through an auxiliary cooler, where the steam condenses. The air is next removed by the wet air pump, which has much less volumetric capacity than would otherwise be required. The hot well pipe is provided with a water leg, as shown, to prevent the air leaking back into the condenser. It is said that this jet does not take more than 1½ p.c. of the steam of the main turbine and increases the vacuum about 1 inch.

In a condenser complete with its air and circulating water pumps the ends of both suction and discharge piping for the cooling water are usually submerged. Hence the circulating pump has only to overcome the friction head of the piping after water has started to flow through the condenser, provided the equipment is not placed too high above the source of supply.

The surface condenser thus provides a high vacuum at a low operating cost. The condensed steam from the turbines can pass directly back into the boilers. The condenser is fairly reliable in operation. Its first cost is high, and it occupies considerable space. It requires a large quantity of cooling water and must be frequently cleaned.

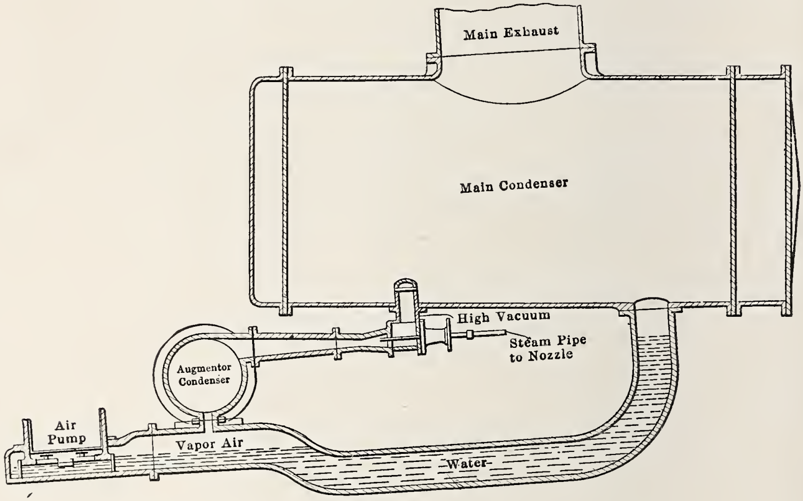


Fig. 6.

Parson's Augmentor Condenser.

Fig. 7 shows an Alberger barometric condenser for steam turbine work. The water is sprayed over the chamber by a distributing cone, which is regulated automatically by the amount of water supplied, which acts against a light spring. A small pipe carries a portion of the cooling water into a chamber at the top in order to thoroughly cool the air which passes up through the hollow stem of the spray nozzle. The air pump suction is thus taken off from the coldest point. The water is thoroughly mixed with the steam before passing down into the tail-pipe. A certain amount of air is carried down the tail-pipe with the water, so that in case the air pump is shut down it is still possible to operate with a small vacuum. The circulating pumps can be installed in duplicate, thus insuring against breakdown.

The cooling water is usually supplied by a centrifugal pump driven by a motor, a steam turbine, or a single engine, as conditions may require. Some manufacturers provide a so-called entrainer on the exhaust pipe. This pocket partially fills with water until the velocity of the steam is such that any further supply of water is carried along by the steam into the condenser. In order to obtain this high steam velocity there must be a marked difference of pressure between the turbine exhaust and the condenser head, which is most undesirable. If it is necessary to remove condensation from an exhaust pipe, it is best to provide a drip pocket in the pipe just before it rises to the condenser, and connect this pocket to a receiver and float controlled duplex pump or a motor-driven centrifugal pump. Such

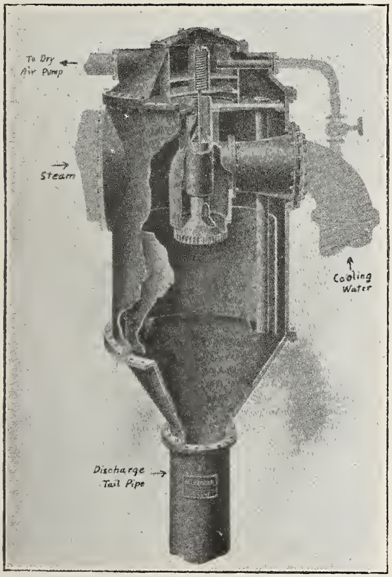


Fig. 7.
Alberger Barometric Condenser.

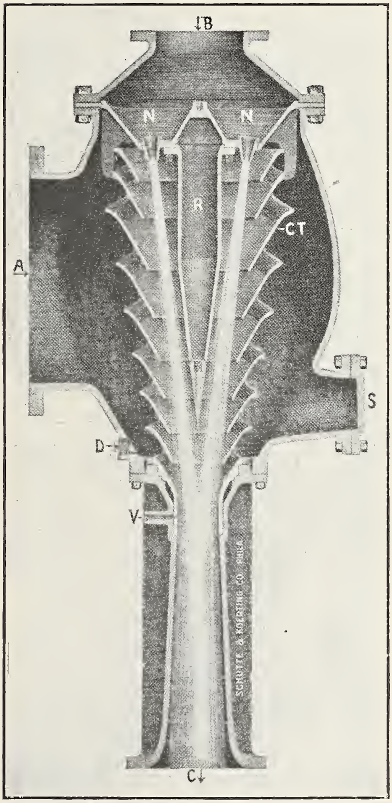


Fig. 8.
Koerting Ejector Condenser.

a pump will readily remove all condensation. This arrangement causes no obstruction in the path of the exhaust steam.

There is practically nothing that can go wrong with a barometric condenser, and as it is impossible to flood the turbine with cooling water, it is the most reliable of all types. Since the water and steam mix very intimately, it will provide the highest degree of vacuum with the least amount of water, and is hence especially adaptable to places where the water supply is small or at a high temperature. It occupies little floor space, and its upkeep is small. The air pump, however, must deal with greater quantities of air and vapor than in the case of the surface condenser, and hence must be larger and more expensive. The circulating pump for the cooling water has to lift a smaller quantity of cooling water against a greater head and hence may be slightly more expensive to operate than in the case of the surface condenser. The first cost of the equipment, however, is about two-thirds of that of a surface condenser, piping included. The condenser discharge is not always suitable for boiler feed purposes.

Another similar type of condenser is the Koerting ejector condenser, shown in Fig. 8. Water is supplied by a circulating pump at a head equivalent to 20 feet of height. This water discharges through specially arranged nozzles into an ejector throat which forms the condensing chamber. The resulting condensed steam and any air present are carried along by the velocity of the water and discharged through the tail-pipe below. These condensers are cheap in first cost, as no air pump is required, and with sufficient cool water will be guaranteed to maintain 28 in. vacuum. Operating costs, when the load is variable, is higher than with a barometric condenser, as the same quantity of water must be pumped at all times, and as this water is under pressure there is also the danger of it entering the engine. The condenser will not work well with warm cooling water. The nozzles are easily stopped up by foreign substances if the water is dirty, and this would tend to destroy the vacuum.

The advent of the steam turbine has probably brought about greater improvements in jet condensers than in any other type. These condensers are frequently used on account of low first cost, of small floor space, and of small amount of cooling water necessary. But the condenser discharge is not always suitable for boiler feed purposes. Reciprocating air pumps have to be large to maintain high vacuum, but simple rotary pumps will be described later, which have proven very satisfactory and economical. There is also the possibility of flooding the turbine with water with these condensers, and each type is provided with some automatic vacuum breaker to prevent this. A few of these new condensers will be described.

Alberger's jet condenser is almost identical with their barometric condenser, except that it is placed at a low level, and the water is forced in by atmospheric pressure. Its tail-pipe has

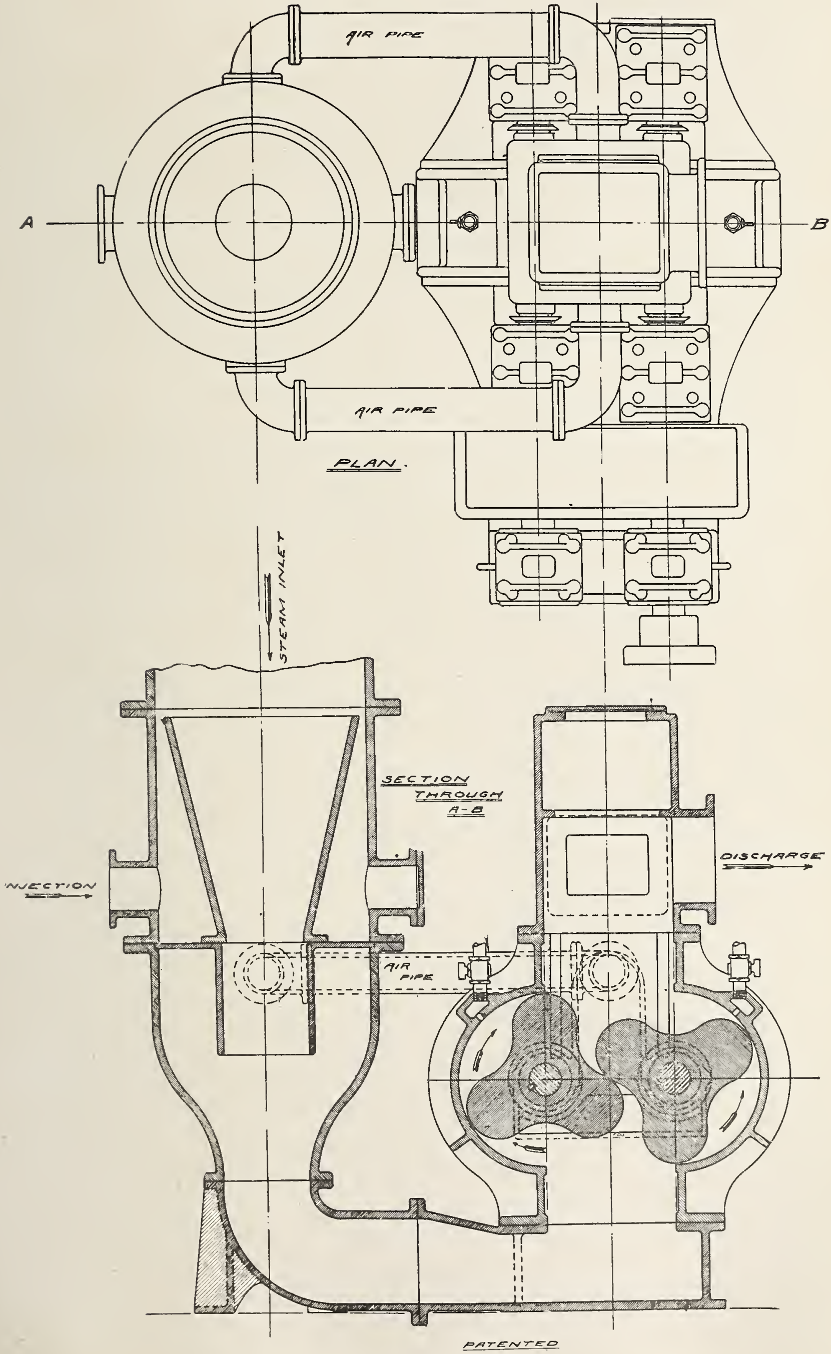


Fig. 9. Connorsville Jet Condenser.

been replaced by a centrifugal pump which discharges both the cooling water and the condensed steam. The air is removed by a standard dry air pump.

Fig. 9 shows a condenser manufactured by the Connorsville Blower Company. The pressure of the atmosphere forces the water into a reservoir in the condenser shell, from which it flows in a thin sheet down the funnel-shaped condensing chamber. The steam enters this chamber from above at high velocity. The velocity of the condensing steam is transferred to the water, which rushes through the throat of the funnel, carrying the air along with it and completing the condensation. The air rises in the chamber around the throat piece, and is cooled by the large body of cold water above it. The cooling water and condensed steam pass to the air pump. This pump is also connected to the air chamber by pipes, and ports are provided in the air pump casing, so that this air enters directly above the water and passes into the space between impellers just before the water is picked up. The pump itself is of the rotary cycloidal impeller type and works on the displacement principle. The clearances between the tips of the impellers and the casings and between the impellers themselves are small, and practically no leakage results, as these are water-sealed, as are also the stuffing boxes. The two impellers are geared together at one end of the shaft and may be either engine or motor driven. Two small cocks are placed on the casing above the impellers, to break the vacuum before opening to discharge. This makes the pump very smooth running.

This is a cheap and very good equipment for water which will not corrode iron. It is also quite economical in the power required to operate it, and has given good satisfaction in a large number of turbine plants where it has been installed.

The shell of the Allis-Chalmers Type C jet condenser is circular in shape, and is erected in a horizontal position. The main idea of the designers was to produce a "rain-storm" effect in the condenser, so that each particle of cooling water, by being brought into intimate contact with the steam, would absorb the maximum amount of heat possible. Hence very little more water need be supplied than that theoretically necessary to condense the steam. The water enters at one end and passes into castiron troughs, from which it overflows through saw-tooth openings. The steam enters at high velocity from the top of the other end and starts to condense on meeting the cooling water. The water then strikes the spray plates below, from which it splashes in all directions, and condensation is completed. The entrained air rises through the water in the left hand portion of the condenser and thus is cooled on its way to the air ejectors. The water overflows at the bottom of the condenser to a centrifugal pump, which forces it out into the waste channel. A second small centrifugal pump, which takes water from the cold well, is mounted on the same shaft as the cooling water discharge pump. This cold water is forced under pressure into an air ejector nozzle, which forms the air pump for maintaining the vacuum. The end of this air ejector pipe is not submerged,

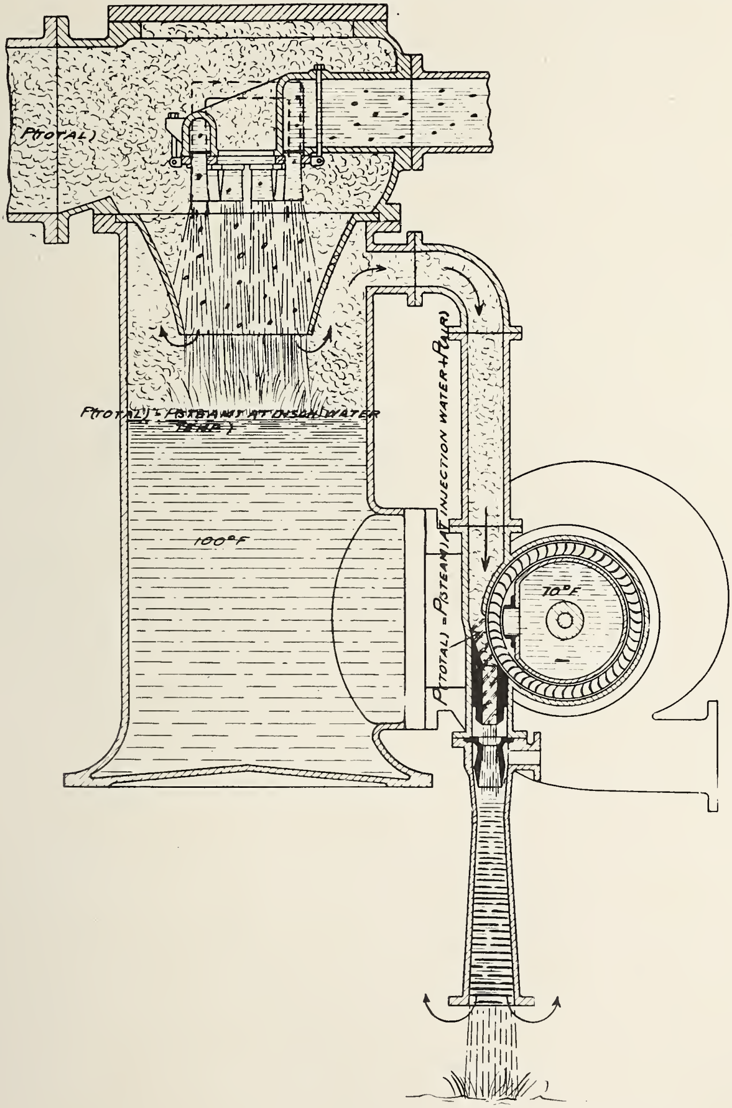

P(TOTAL)
P(TOTAL) = P(STEAM AT DISCH. WATER TEMP.)
100°F
P(TOTAL) = P(STEAM)(AT INJECTION WATER)+P(AIR)
70°F

Fig. 10.
Leblanc Condenser.

so that in case of the pump stopping, air rushes in and breaks the vacuum before flooding of the turbine can occur. These pumps may be motor-driven, or may be turbine-driven, which is the more usual arrangement. This condenser is very efficient in its use of water, but the method of pumping air requires considerable power. A similar method of removing air is used by Brown-Boveri and others in Europe.

The Leblanc condenser, manufactured by the Westinghouse Machine Co., is one of the simplest and most compact units at present built. As usually constructed, the water discharge pump and air pump casings are made part of the same casting as the condenser body itself.

Fig. 10 shows the general arrangement of parts. Steam enters on the left hand side of the condenser head, while cooling water rushes in from the right hand side. The water is sprayed by a distribution head in such a way that it mixes thoroughly with the steam. The discharge centrifugal pump in the base removes this water and condensed steam from the chamber. The air rises into the annular space around the condensing cone and is carried to the Leblanc air pump through the pipe shown. This pump, shown in Fig. 21, is on a new principle. Water enters at the center of the wheel and passes out through the chamber to the rotor. The rotor is provided with a large number of small crescent-shaped bronze blades, somewhat resembling a Sirocco blower. It revolves at high speed and acts like a centrifugal pump, apparently discharging the water delivered from the central chamber in thin solid sheets like so many panes of glass one behind the other with the air trapped between these sheets. In practice this ideal is scarcely realized in full, as the lower sheets of water are disturbed by the splashing of the upper ones on the sides of the air pipe. Whatever the action is inside the pump, the air is very effectually removed, and a high vacuum can be maintained with a total expenditure of power for condenser purposes of about 3 p.c. of that of the main turbine. The pumps may be either turbine or motor-driven.

Dry air pumps play a very important part in the maintenance of high vacua. Fig. 11 shows a section of an Alberger dry vacuum pump, which will illustrate the general principles of reciprocating pump construction. The cylinder is water-jacketed throughout to prevent undue heating in compression and to provide a large volumetric efficiency. The air valve is of the rotary type with ordinary pot discharge valves. The air and vapor enter one side of the piston on one stroke and are compressed and discharged on the return stroke. The valve gear is so arranged that when the piston is at dead center and about to return, a small port connects the two ends of the cylinder. Since the admission has just been cut off from one end, this port allows the highly compressed air in the clearance of the other end to rush over and to partially compress the air which has just entered. In this way the volumetric efficiency of the pump is greatly increased. Mr. F. H. Moody has discussed "Rotative Dry Vacuum Pumps" very fully in Vol. 3 of Applied Science, and no further discussion will be given here except to refer to two types which are so very widely used as to deserve especial attention.

One of these, the Mullan Suction Valveless Air Pump, is manufactured by the Wheeler Condenser and Engineering Co. The cylinder is long and the piston fills almost half the cylinder volume. The air and vapor to be removed rush in when the piston uncovers the port in the middle and are compressed and discharged through the valves in the head on the return stroke. This pump is not provided with the by-pass port described with the Alberger pump.

The other type is known as the "Edwards," which is a vertical wet air pump, and is particularly adapted for working at high speeds. The piston, which is solid and has a cone-shaped bottom, descends to the bottom of the cylinder, which is of similar cone shape. The casing is so designed that the air and condensed steam are driven through ports into the space above the piston. On the return stroke water and air are forced out through the discharge valves in the deck at the head of the cylinder. As the water lies directly above the piston, it fills all clearance spaces before being forced through the valves and acts as a water seal of three to four inches deep on the valve above, very high vacua can be maintained by this type of pump. In Great Britain these pumps are almost invariably used with surface condensers. They are usually built with three cylinders worked from a three-throw crank shaft and motor-driven through

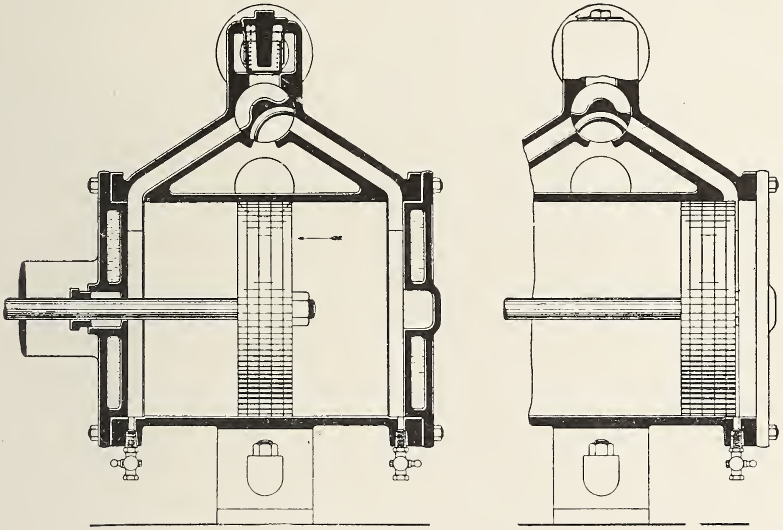


Fig. 11.

Alberger Dry Vacuum Pump.

gearing. An Edwards pump must be placed at a lower level than the main condenser.

In Germany and other parts of the Continent rotary air pumps are being introduced very largely. There are many excellent types of these pumps, but only one will be described. This pump is manufactured by Thyssen. It is essentially a centrifugal pump with full discharge all around the periphery. The discharge from the pump impeller enters a stationary diffuser nozzle, which, in turn, discharges into an air ejector chamber. This pump has proven very satisfactory and quite economical. The A. E. G. air pump is also used extensively. It is quite probable that many of these rotary air pumps will soon be introduced into America, largely on account of their simplicity, freedom from breakdown, low first cost, small size, and ease in operation.

In Europe motor-driven condenser auxiliaries are generally installed, while in America these are steam-driven. If steam is needed to heat the feed water, or if absolute reliability is required, steam-driven pumps should be used. But in other situations, motor-driven auxiliaries may be used. It must be remembered, however, that should the main switches open from a short circuit on the electrical system, the condensing plant will shut down, and all these motors must be started individually before the load can be put on the main engine again. Motors will give trouble if installed in the wet or damp basements provided with poor ventilation and in which condensers are often located.

In conclusion, then, the selection of a condenser should be governed by:

1. The degree of vacuum required.
2. The quantity, quality, and temperature of the cooling water.
3. The requirements of boiler feed.
4. And, most important of all, the first cost and total operating costs of the equipment.

STREET PLANNING.

THOMAS H. MAWSON, HON. A.R.I.B.A.

In approaching the subject of street planning, we are taking up what is, from every point of view, the most important part of city planning, whether considered from the artistic or the strictly practical standpoint. Not only is it the subject which calls for the exercise of all the qualities and principles dealt with in the study of the civic survey, but on the intelligent and masterly solution of the many problems which street planning presents, depends the possibility of success in all those other problems pertaining to park systems, park and street equipment, and housing.

The street planning is the key of the whole subject of city planning, whether considered as a feature in itself or as a basis whereon to build up all the other features of the completed town, and thus we see that, unless every effort is made to deal with this item of town planning in an intelligent and a masterly way, or if a niggardly and parsimonious attitude is allowed to intervene, and prevent engineering and other difficulties from being boldly faced, and energetically dealt with, all our other projects for the health, beauty or convenience of the town must be crippled.

Whatever other economies are effected, there can be no more disastrous policy than not to lay down the roads on the best possible lines, whether they be the most expensive or no. We have always to remember that this feature, more than all others, in a town when once planned is planned for all time, and that if it is ever possible afterwards to rectify initial defects, it will only be at enormous cost compared with that of any necessary engineering involved in doing the right thing in the first instance. I have in my mind in saying this the case of a large estate in the north of England between two manufacturing towns. The first and most obvious necessity in its development was the main through route, crossing the estate diagonally and joining these two busy centres, and this was proposed by the man in charge of the preliminary work, but his strong recommendations were entirely ignored for the sole reason that, at one point, there would be an embankment about seventy-five yards long and some twenty-five feet deep in the centre, and this although, and notwithstanding that, for the rest of its route of over a mile, the road would require nothing but a little cross grading. This is, of course, an exceptional instance of unjustifiable timidity, but I have come across cases almost as bad in my own practice. I do not wish to suggest for a moment that Toronto would ever be guilty of such shortsightedness, but everywhere there are a few people who would be penny wise and pound foolish if allowed their way, and I, therefore, give prominence to this point at the beginning of this paper, that your hands may be strengthened to resist the importunities of the fearsome, when the time comes to determine the routes to be laid down for future development in your own city.

The moment we approach the problem itself we find that expert town planners are divided into two great schools, each having their own methods of development, and known as the medieval and modern schools of street planners. The former of these argues that, whereas ancient medieval towns are more picturesque than modern ones, the true road to picturesque town planning is found by copying the old examples with their lack of all method or purpose. The fallacy of this argument is immediately apparent if we consider for a moment wherein the picturesque quality of old cities consist. Undoubtedly it is in their history and the spirit of romance which clings round ancient cities that most of their beauty is found, and, in its very irregularities, the eye seeks to read a purpose or cause, and so sees, written on the face of the town itself, just as one does on the human face, a history of its trials, vicissitudes, greatnesses and meannesses in a manner which strikes a sympathetic human chord and fills us with a love of the antique. When we point out the possibility of reproducing this haunting presence, this indefinable, sympathetic, almost human trait in old cities, we see the fallacy of trying to copy old methods in our town plans, and realize that any attempt to do so must produce an artistic sham, than which there can be nothing more irritating to the aesthetic sense.

There is another side of the question, however. These zigzag streets, now broad, now narrow, and meeting each other at all sorts of inconvenient angles, are quite unsuited to modern traffic requirements, which must be studied and met if our street plan is to be complete. Both on the practical and artistic sides of the question, too, there is a still further objection to this form of planning, for it invariably results in a multiplicity of little aims; on the one hand, little ends of streets and lanes embarrassing to the driver of wheeled traffic and little vistas, each with its little terminal clock turret or other feature, the constant repetition of which tends to become irritating to the artistic sense.

For these and other considerations arising out of them, and which are so obvious that, even if the time could be spared, I hardly need stop to labor them, we are forced to the conviction that, to copy old methods because they are old, cannot but be a fatal policy, and that street planning, if it is to be successful, must be the logical outcome of practical needs met and fittingly clothed with a garb of greenery, and its lines emphasized by the accompanying architectural features.

I do not wish, by this statement, to imply that all features which are spontaneous should be refused a place in street planning schemes, and that they should wear a manufactured air, owing nothing to Nature or local conditions. Far from it, for it is by the skilful use of any advantages which local conditions place in our hands, and even by the effort to overcome disadvantages, that our best results are achieved, and new work is made to fall fittingly into its place, for what we are apt to call "distressing newness" in a newly developed neighborhood is merely this—that what has been done clashes with our sense of fitness through unsuitability to its environment, and that we look to time, that great remover of invidious distinctions, to complete our work for us and cover our mistakes.

As an example of a street in which a splendid result has been attained, partly by the aid of art and partly by the aid of natural features, we can have no better example than Princes Street, Edinburgh. Here we not only have the street itself well proportioned in length, breadth, and the height of the buildings, bordered with gardens, and so the best that art can provide, but we have the undersigned juxtaposition of the Castle and the fine view of Calton Hill, and, further still, the fact that the acropolis on the hill has never been finished, which is deplored by many people, but which we are inclined to look upon as one of those fortunate accidents to which the civic architect is so often indebted for his finest effects, for, were the large classic building completed, the effect would be heavier and less graceful than at present.

We thus see how many-sided the interests of the street planner must be if he is to make the best of his opportunity. While he must have a thorough technical training, he must avoid at all costs that fixity of outlook and inability to gauge the aesthetic possibilities of his subject, which is the bane of the man educated in exact sciences such as road engineering. In fact, the man who can successfully plan the roads of a city in advance so as to produce the best result from every point of view, must combine a knowledge of precedent with inventive genius and a complete mastery of technique, with the ability to throw overboard all his school-learned formulae, at a moment's notice, where the exceptional nature of the case demands this, and, again, while using every available aid of modern science, to take Nature as his guide and learn from her to clothe utilitaria with beauty and combine freedom with the ordered neatnesses inseparable from our highly complex modern existence.

If, then, the haphazard and slavish imitation of the old will not do for the modern town, it remains for us to determine the principles on which successful street planning must rest. In dealing with this subject, it is necessary to classify the streets to be formed into broad groups, according to their purpose, as the requirements of each kind differ in almost every way. This is usually done by dividing them into traffic and non-traffic streets, but, in most instances, such a division is too sweeping, and many different kinds of roads are thus lumped together quite unjustifiably, and no place is given to open spaces in either category. I would divide them into monumental open spaces, recreational open spaces, traffic places, markets, shopping and business places and streets, main through routes, main residential thoroughfares, secondary residential streets, main arteries of the manufacturing district, secondary manufacturing streets. This gives us as many as nine main divisions, but even then cases are constantly arising of streets which cannot be included under any of these heads, without straining a point, and, of course, in special cases, there will be other special classes, such as the cathedral town with its close, the shipping town with its wharves, and so on.

With the open spaces, considered as such and not as traffic centres, dealt with in another paper, I propose now to examine some of the various attempts which have been made at orderly planning, and I think we shall find that the more the existence of these fundamental differences in the functions of different classes of streets and highways is recognized, the more successful is the plan.

We begin, then, with the "gridiron" plan, which is found in the remains of the Roman colonies; and even earlier than that, we have the earliest known effort at comprehensive planning in the ancient town of Kahun, as drawn and described by Professor Flinders Petrie, which is in this same gridiron system of planning, and again at New York, San Francisco, and many towns commenced during the last century, we have the same thing. In Bloomsbury, London, the same style of thing was done, and many other towns have been partly laid out in this manner.

That a style of planning so primitive and ancient is not well adapted to modern conditions we should be prepared to find, though it may sometimes be adopted for small areas with great success, especially if the architectural features bear strong evidences of a classical influence. Such a case is found in Edinburgh, where the district to the north of Princes Street is most successfully laid out on this principle, and it is much to be deplored that, when the coming of the railway upset the scheme, nothing was done to insure its replacement. Development ever since has gone on on the meanest lines.

The chief fault of the gridiron plan, from a practical point of view, is that it only allows of through traffic routes in two direction, and that traffic proceeding diagonally across the plan is compelled to take a zigzag course, which means much loss of time at every corner, not to mention the extra distance traversed. So greatly has this been felt in towns originally laid out on this principle that great efforts are now being made to superimpose diagonal lines into the original layout. Philadelphia is a very typical case.

Some cities have attained this combination of gridiron and diagonal lines by chance, or rather, by the compelling force of circumstances, which is a strong point in its favor. Generally the diagonal lines have been evolved first and the square lines added afterwards, as at Calais, in France.

From the aesthetic point of view, the gridiron plan is also very undesirable, not only from its monotony, but also because it does not provide sites at the ends of long vistas whereon to place important buildings, and so the necessary perspective cannot be gained to view them properly. In many towns, too, where the streets are near together, this form of planning has resulted in there being no parcel of land big enough for the site of an exceptionally large building, and so excessively and undesirably tall buildings result.

Even the superimposition of diagonal lines will not entirely do away with these defects, though, that very much may be accomplished is evident from the detail plan of the proposals for a parkway from City Hall to Fairmount Park, which forms part of the scheme Philadelphia already referred to. Nevertheless, these efforts all partake of the nature of patchwork improvement, showing that the principle is at fault, and should not be adopted for new cities.

The better way is found when we come to study the traffic and other requirements to be faced. We then see that three-quarters of the traffic in every town proceeds to or from a point near the centre and the suburbs or surrounding country. This means that three-quarters of our traffic streets should radiate from the centre of the city to its boundaries, and further study will show that, in all ordinary cases, the remaining quarter of the traffic gyrated round that centre so that, if we do the best for the traffic, we have a plan which follows the lines of the spider's web.

A further development of the radial plan is what is known as the "ringstrasse," as it has been more extensively adopted so far in Germany than elsewhere. It consists of a ring of parks round the central part of the city, and, in old cities, has usually been obtained by clearing away obsolete fortifications. Vienna gives the best example, where a very fine use has been made of the opportunity there afforded.

In a theoretical case, then, our plan will consist of a series of radial streets and another system encircling the point where all the others join. At the latter point will probably be placed a large open square or plazza, in the centre of which may stand the chief building of the town, say, the cathedral, university, capitol or commercial exchange, according to whether it is an ecclesiastical, educational, administrative or commercial centre. We are, however, at once confronted with two difficulties, which are, that our radial streets will be too far separated in the outer parts of the town, and that so many streets, and consequently so much traffic, crossing at one point, will create great congestion in the central square, which is highly undesirable round an important building or group of buildings of the nature suggested. Here the ringstrasse comes to our aid and provides not only trees, greenery, water and the songs of birds, within a moment's walk of the busy offices in the centre of the city, but also the opportunity of providing interlacing roads, which are really short cuts, diverting all traffic from the central square, which is not destined for a point exactly on the opposite side of it from that which it starts. It also provides for the arrangement of a series of secondary radial roads which do not proceed right into the centre of the town and so are not traffic routes, but merely means of access, and do not proceed out into the country, and so leave large sites available for industrial purposes or for development as individual units for residential suburbs.

Such a plan could never, of course, be carried out without adaptation to the needs and possibilities of an individual site, nor is it desirable that it should be, but the principle may always be used, and has been in many instances. It seems equally suited to a large town or a small suburb.

This indicates another way in which the radial system of planning surpasses the gridiron plan, that is in its adaptation to and recognition of the contours. Its adaptability to various conditions met with on the individual site, which are never the same on any two pieces of work, must necessarily be much greater than a collection of stiff straight lines crossing one another at right angles, and necessarily so near together that no deviation to meet the contours is possible.

In a number of instances the curved roads are not struck from a centre, but deviate somewhat. This is for the purpose of meeting the contours, and, in fact, these lines were laid down on a carefully prepared contour plan, as all such work should be. The adaptation of the lines of roads to the contours in this way has both practical and aesthetic advantages. Not only does it allow of easier gradients, making traffic easier, but it also expressed, in a logical and straightforward way, the prevailing characteristics of the surrounding country, and, as no two sites are alike, provides infinite variety.

The fan-shaped construction of this plan also brings up another point. Where the town is a port on the shore of a large river, or lake, or the sea, we have a variation in the traffic problems to be met, for not only will there be the traffic radiating from and gyratory about the centre, but also traffic proceeding from the wharves and warehouses along the shore inland in all directions. The fan-shaped plan allows of this in a very simple manner, for the circular roads, at the water side, become a means of reaching the centre of the town from every point where they touch it. This has evidently been realized by the city officials at Liverpool, who are at the present time constructing just such an avenue enclosing their city, and most town plans of recent date for cities on a waterway, such as Mr. Burnham's plan of Chicago, recognize it.

The plan of Copenhagen is very interesting in this respect and shows that what was intended primarily as a gridiron plan has evolved these very characteristics from the force of circumstances in a manner particularly adapted to the site which is on a peninsula.

We have not yet exhausted all the advantages which the radial plan has over the gridiron, however, for it has the additional advantage of allowing of town gardens, squares, and open spaces, in the placing of which there is an obvious raison d'etre which is absent in the rectangularly planned town. In the latter, when you want an open space of any kind, you simply miss out one, two or three blocks of buildings, as the case may require, and the fact that this may be done anywhere at random gives the result the appearance of being the outcome of an arbitrary apportionment. In the radially planned town, however, there are numerous sites where roads divide, and so on, which call aloud for treatment as open spaces, and so, when this obvious need is fittingly met, we have a sense of fitness which adds greatly to the aesthetic effect. I need hardly add, too, that where two roads converge at either side of an open space, where drivers of traffic along one road can see that approaching the point of junction by the opposite road, there is much less danger of collision than where they meet suddenly round a corner in the square plan. In the radial plan, too, where they approach each other obliquely, the two streams of traffic unite or cross much more easily than where they cross one another at right angles.

This brings us to the important and, in some of its connections, very abstruse question, of traffic circulation and control. To deal at all adequately with this one aspect of street planning would be quite impossible in one lecture, but I think that we shall have enough time to look into some of the main problems in this department, the solution of which suggests methods of dealing with all the others.

The most important traffic question of all relates to those points in the busiest parts of the town, where the traffic has a tendency to converge on one point and so create congestion and delay. Those of you who know the Old Country will know what I mean when I instance the great traffic crossing known as "The Bank," in London. We have a local example here in Toronto at the corner of Yonge and Queen Streets.

The axiom one finds in books on town planning with regard to these places is that, "The multiplication of traffic places should be avoided." Now, while I entirely agree with what the writers mean when they say this, I think it may be far better put by saying that, "The points where traffic crosses should be multiplied, so that a large number of streams do not converge at any one point." This, I take it, is what is meant by the previous assertion, for streams of traffic proceeding in every direction must cross somewhere.

One way of overcoming the inconvenience of a number of streams of traffic converging on, and recoiling from one point, which has been very much discussed of late, and which has attracted a very considerable attention, is what is known as the gyratory circulation of traffic. The principle is that, wherever the traffic enters the open space at the junction of the roads, it should all proceed round the space in one direction until it reaches the road leading away from the centre which it wishes to traverse, when it would naturally and easily fall out of the stream. This idea would work most excellently for street cars on rails, but there would be considerable difficulty in persuading the average driver to go round three parts of the circle to reach the point he wants, when the fourth segment is so much shorter, and the more democratic the local sentiment, the greater the difficulty. Many devices are proposed for overcoming this defect, the most usual being to make the roadways approach the open space tangentially, so as to bring the traffic into it pointing in the direction in which it is proposed it should gyrate. Unfortunately this involves the slowing up of the traffic at the point where it leaves the traffic centre in order to turn a sharp corner, thus neutralizing the chief advantages claimed for this system, and I have not yet seen a really successful attempt to overcome this difficulty. The aesthetic possibilities of the two systems are quite different. While there are numerous examples where the vistas down the four streets converge on one focal point in the centre of the square, which would, almost necessarily, be graced by a fine architectural feature, such as a clock tower or fountain, in other cases we have separate vistas not calling for such heroic treatment, but providing a fine opportunity for an extra bold treatment of the facade at the point where it comes across the view down the street.

There is yet another means of overcoming the dislocation of traffic, which occurs where two streams cross, and this is the superimposed thoroughfare, that is to say, by carrying one road over the other by bridge. We have done this in London by means of the Holborn Viaduct, and the plan has proved to be all that could be wished on the practical side, though one wishes that the bridge were more successful architecturally. Crescent roadways are provided to accommodate this traffic, and there is no valid reason, except expense, why these quadrants should not be adopted everywhere where two important traffic roads cross, whether they are superimposed or not.

Much more might be said on this most interesting subject, but we must now turn to the planning and arrangement of the streets themselves as separate units. We deal with the proportioning of streets, avenues and boulevards in another paper, and I only propose here to touch upon one or two of the most important practical questions relating to formation, width, route, and traffic disposal.

In Britain our great trouble is the standardized street. That is to say, the law has endeavored to find one kind of street which will suit every possible case, and enact that this street shall be used always without variation. In England we call it the "by-law" street, and it is either thirty-six or forty feet wide, with the whole surface either macadamized or paved, and, up to quite recent years, trees could only be planted in it by persuading the law to shut its eyes to their existence. How this kind of thing works was very well illustrated by a case reported in the "Surveyor" a few years ago. The proprietor of a piece of ground, through which an exceptionally picturesque stream flowed tumbling over the rocks in a tiny ravine, desiring to make the most of this exceptional feature, proposed to preserve it as an open space in a railed-in enclosure in the centre of the street, placing eighteen feet of the thirty-six foot road on either side of the open space, and having the houses to face onto it. This was declared illegal, and, as the rental of the houses would not bear the cost of making two thirty-six-foot roads, one either side of the stream, the latter had to be placed in a culvert or sewer and the street carried over it. Note the result: Whereas, had the artistic arrangement first proposed been carried out, there would have been about a hundred feet of open space and light and air in front of each house; in the one adopted the house fronts were within forty feet of one another. Truly, in this instance, therefore, the immortal dictum of Charles Dickens' hero that "the law's a hass" has been vindicated..

I would, therefore, say to the people of Canada, whatever you do beware of the standardized road. Of course, municipal control of some sort is necessary, but it must be much more elastic than has usually been the case with us. What is really necessary is not to ensure that every road shall come up to a certain standard, but that it shall provide light and air to all the buildings bordering it, and shall be of sufficient width for the traffic. It should, too, be so planned that, should the traffic increase, the amount of road surface can be added to without expense and without setting back the frontages of buildings. Surely, what matters from the health point of view, is not the width of the road, but the distance between the houses on either side of it. These considerations have led the promoters of many garden city and suburb schemes to propose that land to a considerable width should be reserved for each road, and the frontage line of the buildings be kept well back from it. A strip in the centre, broad enough for immediate requirements, is macadamized or paved, and the remainder is laid down with grass and planted with trees, with or without flower beds, according to circumstances. This method has been adopted in the case of the new ring road round Liverpool already referred to.

Another method is to divide all roads into traffic and non-traffic, as in the town planning scheme already described, and formulate separate by-laws for each. Not only is this method far too wooden in its classification, but, as the non-traffic roads are far the cheaper to make, there is a tendency towards their multiplication and the provision of too few through routes. Whichever system is adopted there is a tendency to the creation of little cul-de-sacs, which would be very difficult to police efficiently.

The great difficulty in planning a new street is to persuade the promoters of the scheme to make it broad enough. What looks very generous on paper, and even absurdly so, while the place is in a young and growing state, will be found to be less than is desirable when the town has fully developed. This is the reason why none of the recent town planning schemes in England have their main streets as broad even as the old village high streets, in the surrounding villages, and yet there are plenty of people who consider the widths laid down as excessive.

While these few notes must suffice for residential streets and non-traffic roads, for the others, a few words must be added as to the disposition and arrangement of traffic. This is a most important subject, which has come very much to the fore of late years, owing to the introduction of automobiles and waggons, which have revolutionized the question in England, and must do so in Canada also, though as yet, I understand, you have not the traction engine, with its three or four huge trailers holding perhaps ten tons of merchandise each.

We all know, however, and can easily see what enormous development of the commercial and manufacturing businesses must take place in this country within the next few years, and, this being the case, we must be prepared for an increase in the heavy traffic and provide for it in our street planning. It is accepted as a principle that, in planning streets where the traffic will be heavy, an effort should be made to keep light and fast traffic separate from heavy and slow moving vehicles. This is generally done in important streets by the provision of separate tracks for each class of traffic. In every case, whether separate tracks are shown or not, the fastest traffic takes the centre of the road and the slowest the sides, which is really the only practicable arrangement, though, undoubtedly, if the road slopes into the gutter at the sides, as it should, heavy wheeled traffic has a tendency to slide into the gutter, so that, in the case of that drawn by horses, they are, as it were, pulling uphill all the way. For this and other reasons mostly of a purely theoretical nature, I have heard it argued that the reverse order should obtain, and the heavy traffic take the centre of the street, but anyone who has watched really heavy traffic, say on London Bridge, will realize at once that this is quite impractical.

A factor which greatly complicates the whole question, especially in old towns such as London, is the obstruction caused by the vehicles standing by the sidewalk to discharge or load. If one compares the ease with which the traffic proceeds on one of the bridges across a wide river like the Thames in the centre of a large town, with the congestion which obtains on either approach to the bridge, even though the latter are usually broader, this will be abundantly evident. In the planning of a new district, however, this can be very easily avoided, either by making narrow side tracks next to the sidewalk, especially for vehicles standing still, with, say, a strip of grass and trees between it and the main roadway, or, where this is undesirable, by the provision of a secondary means of approach at the rear of the building facing onto the main thoroughfare. In either case, however, there is no doubt that there should be statutory power to compel persons carrying on the business of public carriers, auction marts, or other business where goods are constantly arriving or departing, to provide proper yard space for their vehicles. In short, there should be some limit enforced as to the aggregate length of time in each day vehicles may stand still on each part of the highway, and persons causing them to exceed this should be liable to summons for causing an obstruction.

There is a further method of relieving congestion in the streets, which is by raising the street car traffic, with its railed track, above the rest of the traffic, or sinking it below. Of the two the latter method is by far the best, as, if we raise the railed traffic overhead, as in Berlin and Liverpool, the track shuts out the daylight, and the noise is deafening, whereas, if we sink it into a shallow subway under the street, as in the case of the London Underground, none will be aware of its existence until informed of it. Where the sunk track is arched over and the street carried above it, the expense is, of course, very considerably greater than that of laying the tracks on the surface, often prohibitively so, but in planning a new neighbourhood, there is no need to do this, for the cutting in which the cars run may be open to the sky for the greater part of the distance, with frequent bridges over to allow traffic and passengers to cross the street. This has also the advantage of letting daylight into the cutting, and where the space could be spared, the sides might be formed into sloping banks to be clothed with grass, flowering shrubs, ferns or creeping plants, according to the locality, or the street on either side of the track may be undermined to provide sidings for good waggons, which, if a track of the standard gauge were adopted, could thus be run off the railways right up to the warehouse door. Of course, in great cities separate tubeways would be provided for the collection and delivery of goods, but this combined passenger and goods street railway would suffice for all ordinary cases. The advantages in sinking the street railways into an open cutting are thus two. Not only is it possible, as just described, to arrange for goods traffic in a way that would not be possible on the surface, but also the cars can proceed at a pace which would otherwise be dangerous or impossible. The advantage where a traffic place is crossed, too, is very obvious.

Deep tube railways, such as we have in London, are only suitable for certain geological formations, so I shall not discuss them at length. I may, however, say that it seems a great pity that more could not have been done to obtain wayleaves under the buildings instead of keeping strictly under the streets, as, in that case, they could have been better arranged, so as to have been capable of being driven at high speed. The chief objection to this class of conveyance is the time spent waiting for elevators, and attempts are being made at the present time to obviate this by the introduction of continuous moving platforms or staircases, which can be stepped onto at any time and immediately commence to convey the passenger up or down. The first of these, just opened as I write this, is so successful that it is anticipated that before long they will be adopted at all the London tube stations.

There is one great factor in the street planning of a city or town which is so important that I have reserved it for discussion at the last, that we may be able to give it individual attention. This is the relation the street planning must bear to the entrances to the city. In the past, before the advent of modern civilization, as we understood it to-day, the entrance to the city was by the imposing gate in the city wall, with its drawbridges and portcullis, as in the case of the gateway at Lincoln, which remains to this day, as do the gates to many other cities in the Old Country, such as Bristol and Coventry.

Even when the need for a fortified gateway has disappeared, it was still felt that this was an important point in the aesthetic sense and ought to be marked by a suitable erection, for in the year 1670 the bar, posts, and chains, which were all that were left to show where the old gate had stood up to the time of the Great Fire were removed, and the Renaissance archway, with a room over it, which we all know so well from pictures, was erected at the main entrance to the city of London. Even later, that is, at the end of the eighteenth century, when there could be no possible utilitarian necessity for a city gate, Sir John Soane and others formulated a strongly supported scheme for a portal entrance to London at Tyburn, that is what we now call Marble Arch, and the original of which is in the Soane Museum, in London. It was designed on very fine lines and would have formed a most imposing feature. The coming of the railway, however, upset all such plans and altered the situation entirely. Nowadays the grand portal entrance to every town is the principal railway station, and the oldest big railway in Britain, the London and North Western, fully realized this, and planned their station in London on what must have been, for the immediate requirements of the time, truly magnificent lines, though modern developments have placed even it somewhat out of scale.

In the city of the future, however, there is no doubt that the grand portal entrance is the railway station, and the traveler's first and most lasting impressions must not be of dirty back yards and a muddle of traffic, such as surround most of the railway stations of the Old Country, but of a station so placed as to show the city at its best. There is no reason why the railway station should not focus and be emblematic of the city's commercial life, just as the church or cathedral is of its religious life. We in the Old Country are so unused to any such feeling that to propose that these two emblematic erections should stand facing one another at opposite ends of a finely proportioned boulevard, each suitably designed to express its several purposes, would tend to raise a smile, but there is nothing wrong with such a view. On the contrary, in fact, there is everything to commend it, and, where other conditions are favorable, there is no reason why it should not be carried out with the best possible results, thus helping to make the dead stones of the city's buildings speak of the living activities within.

UNIVERSITY OF TORONTO ELECTRICAL CLUB.

The first regular meeting of the club was held Wednesday evening, Nov. 8th. The president, Mr. F. C. De Guerre, made his inaugural address, thanking the members for their expression of confidence in him by electing him to such a responsible position. He outlined the constitution of the club and called the attention of those present to the splendid opportunities afforded the members, of hearing addresses on live engineering subjects, by men who are a success in their respective branches.

Professor R. W. Angus was then asked to address the meeting, his subject being, "European Laboratories, Workshops and Power Plants." The speaker, before introducing his subject, began by telling of many amusing incidents of his trip through Europe. He then described, by the aid of lantern slides, many of the technical schools and engineering works which he visited.

The speaker emphasized the fact that our school has been criticized for its lack of working models, and stated that, although the European technical schools have models of almost every conceivable device, they do not seem to be used by the students to any great extent, but simply exposed to view in glass cases. The subject of the use of small machines, such as we have in our laboratories, was mentioned. Professor Angus stated that in many of the German schools large machines are used for experimental work, but he believed that the principles of the work requiring the use of machines could be more effectively taught with the aid of comparatively small apparatus, the only real gain in using larger apparatus being a probable increase in efficiency.

The address was most interesting and instructive, and a hearty vote of thanks was extended to the speaker.

There is an erroneous idea among some of the men that because the club is called the "Electrical Club," it has no interest in mechanical work. The constitution clearly states as one of the objects of the club, the reading and discussion of subjects of direct interest to third and fourth year mechanical and electrical students, and also the debating of such subjects. In accordance with this, the papers are divided equally between the two branches.

These two branches of engineering have such a close connection, it would hardly be a successful venture to have two separate clubs. Also, during a course in an engineering school, it is not advisable to make the education too narrow, and the subjects which are of interest to students in electrical engineering should be of equal interest to those who favor the mechanical branch. Especially should this be true of third year men, who, in very few cases, have decided definitely in which of the two professions they are the more interested. For these reasons the club executive hopes that all who are interested in these two branches of the engineering profession, especially third and fourth year men, will become members of the club and be regular attendants at the meetings.

Several very interesting papers have already been secured, and the year which is now before the club promises to be one of the brightest since its organization.

The club held an excursion on Nov. 8th to the Strachan Avenue sub-station of the H.E.P. Commission. Quite a number of the members availed themselves of the opportunity of seeing one of the most interesting high tension stations in America. Many other excursions to places of interest are being planned, announcements of which will be given later.

A NEW SCHOLARSHIP.

Since the beginning of the term a scholarship has also been offered by the Boiler Inspection and Insurance Company, of Canada, Limited. It is open to students of the third year in Mechanical Engineering, and is to be awarded to the man who stands first in honors in this department at the annual examinations. The scholarship is to the amount of $130.00 (the tuition fees for the fourth year). The donation has been very highly appreciated by the institution, and Mr. Roberts, the secretary of the firm, has been the recipient of praise and hearty thanks from the staff and the undergraduates. It is felt by them that the interest taken in the work of the institution by engineering organizations is very rapidly increasing, and no better acknowledgment of this appreciation is more encouraging than the granting of such a scholarship.

A. H. Munro, '10, is on construction work for Smith, Kerry & Chace on power development at Auburn, Ont.

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THE EVOLUTION OF VERTICAL LIFT BRIDGES

Henry Grattan Tyrrell, C. E., '86.

Hew down the bridge, Sir Consul,
With all the speed ye may,
I, with two more to help me,
Will hold the foe in play.

And Fathers mixed with Commons,
Seized hatchet, bar and crow,
And smote upon the planks above,
And loosed the props below.

But meanwhile axe and lever
Had manfully been plied,
And now the bridge hangs tottering
Above the boiling tide.

And with a crash like thunder
Fell every loosened beam,
And like a dam, the mighty wreck
Lay right athwart the stream.

The development of constructive types forms an interesting study and usually shows that the designs for many recent works are based upon earlier and often very unpretentious ones, modified to suit local requirements. It is only by following these developments that it is possible to appreciate the degree of merit or originality which any new creation may contain. Movable bridges have been used for many centuries, some writers contending that the bridge over the Euphrates River at Babylon (B.C. 783), built under the direction of Queen Nitocris, was arranged with movable platforms, which could be withdrawn at night to prevent thieves from entering the city. Pons Sublicius (B.C. 621) over the Tiber at Rome, is described by some historians as having been of the same type, but the description of its removal, as given by Lord Macaulay, does not indicate that it contained any parts that are easily moved, some of his references being quoted above.

Though the accuracy of these early traditions will probably remain shrouded in mystery, it is well known that movable bridges of the bascule type were very common during the Middle Ages, especially at the approaches to castles and walled cities, and quite elaborate drawings of such bridges are still extant, exhibiting a degree of inventive skill that has not been surpassed even in our own time. Indeed, most of the patented inventions of the last twenty years are merely revivals of earlier ones which were studied out or built during previous centuries, and many features of modern bridges, originality for which is claimed by recent proprietors, are found to have been in use long before the advent of the present generation. There is, therefore, no branch of engineering in which a knowledge of history is more essential.

Movable bridges of the direct lift form are, however, of more recent origin, one of the first appearing previous to 1840, in the wooden trestle of twenty-three spans, over the Danube River at Vienna, the floor over one 30 foot opening being arranged to lift 6½ feet. There was also, in 1846, on the Amsterdam and Rotterdam Railway, over the Poldervaart—a canal on the Polders—a bridge with two side openings of 21 feet and a center one of 13 feet, the last capable of being lifted about 5 feet vertically, by means of a crab and screw worked by hand power. It was a small structure, only 55 feet long and 10½ feet wide, with floor less than 10 feet above water. Piers were on a slight skew and were founded on piles. The next vertical lift bridges appeared in England, two being placed over the Grand Surrey Canal at London (1848), under the direction of Robert J. Hood, to carry the Thames Junction branch of the London, Brighton and South Coast Railway. These bridges crossed the canal and tow path and the larger one had a span of 35 feet between tower faces, though the channel opening was only 21 feet. It was 83 feet wide with a rail-track on one side. The moving platform, weighing 12¾ tons, was suspended by wire ropes over sheaves on top of four disconnected cast iron towers, and the 12½ tons of counterweight descended into underground cast iron cylinders. It could be lifted by two men on a hand winch, the greatest rise being only 5 feet. The other bridge over the same canal was 12½ feet wide and 31½ feet long, the upper end of towers being connected by braces with curved bottom cords. Chains were used for the suspenders instead of ropes, and the rear tower faces were curved, giving them a graceful appearance. The total cost of the latter was $6,500. These two bridges over the Grand Surrey Canal, were probably the first properly constructed ones of the vertical lift type, and for more than sixty years have served as prototypes for many later and larger ones.

Following these, there appeared at least four fine designs which have hardly been excelled, and certainly not in artistic merit. The first was in the international competition of 1850 for a bridge across the Rhine at Cologne, which brought forth no less than sixty-two competitive plans, one of which by Captain W. Moorsom, of London, contained a centre lifting span 100 feet long, between 600 feet through side lattice girders. Provision was made for a 25 foot street and two railroad tracks, with footwalks on an upper floor. The under clearance of the bridge when down, was 50 feet, and 104 feet when at its highest position. The first prize in the competition was awarded to J. W. Schwedler, of Berlin, for a three span bridge with a central double bascule, somewhat similar to that afterwards used for the Tower Bridge at London. But Captain Moorsom's design was notable for being the first important one of its kind, being used even now as a model for succeeding ones. Its estimated cost was $1,184,000. In 1867 a design was made by Oscar Roper of Hamburg, for a bridge over a wide river, containing a 300 foot lift span, which could be raised to allow ocean sailing ships to pass under it. Another large bridge was proposed in 1872 by T. E. Laing, for carrying a railroad over the River Tees at Newport near Middlesbrough, England. The centre lifting span had a width of 200 feet, and under clearance of 50 feet when down, and 90 feet when raised. The principals were heavy plate girders 200 feet long—very bold indeed for the time—rising between stone towers which had recesses for the counterweights. Provision was made for a variation in the counterweight by adding or withdrawing water, supply tanks for the purpose being placed high up in the towers. To lift the bridge, water would be run into the tanks on the counterweight, when it would automatically rise, and to lower it again, the water was withdrawn until the balance weights were lighter than the span, causing it to descend. Sand glasses were proposed for gauging the amount of water needed. Another elaborate design for a lift bridge appeared in 1878, in a bridge of five spans to cross the Scheldt at Antwerp, the work of M. H. Matthyssend. It had two shore openings of 178 feet (59 meters), two over the main channel of 472 feet (150 meters), and a central lift with clear width and height of 131 feet (40 meters). All trusses had curved upper chords, and multiple web members, there being provision for a 19 foot road, two rail-tracks and double sidewalks. The towers were carried out in stone the tops being connected in both directions by struts with curved lower members. The fixed spans and the centre one when down, had an under clearance of 43 feet, sufficient to pass all ordinary craft. These four designs for lift bridges at Cologne, Hamburg, Newport and Antwerp made with masonry towers and before the days of structural steel, are the prototypes for many important and later ones, and contain much of artistic merit.

Going back a few years to France, it is found that a lift bridge of unusual design over the Ourcq Canal at Paris, on a slight skew, was completed in 1868 to carry a line of railway, the height of which was only 14 inches above the surface of a 28 foot channel. A lifting platform was suspended between two brick arches 28 feet apart, having a clear span of 66 feet and 21 feet rise, and when raised, the under clearance beneath the platform was 16½ feet. The brick arches were 6½ feet wide and 3½ feet thick at the crown, and brick pillars at each end with guide grooves for the counterweight supported the 4 foot sheaves and the shore ends of lattice girders. The weight of moving platform was 22 tons, which was balanced by an equal amount of counterweight, suspended by chains over sheaves, on the face of which were depressions to prevent the chains from slipping. Stairs at each end led up to an elevated foot walk which was always accessible. The platform remained up at all times excepting when wanted down for the passage of a train, after which it was raised again. It was operated by hand power. Another lift bridge somewhat similar to the last, was placed over the Rhine-Marne Canal in 1872, overhead girder supports being used instead of brick arches. The canal had a width of only 12 meters, but the distance between the approaches, including the two tow paths, was 24 meters, and the over-all length 29 meters. Suspenders attached to the ends of brackets on the main girders, passed over sheaves on the upper framing, and were attached to counterweights at the ends. The framing lacked rigidity, as it was braced transversely only by the stairs leading up to the upper level.

One of quite different design was erected in 1873 at Dublin to carry a line of railway over the Royal Canal entrance at Spencer Dock, on a skew of 25 degrees. It is described as weighing 14 tons, the bridge being balanced with counterweight consisting of tanks filled with water, the tanks when empty being one ton lighter than the bridge, and when loaded with two tons of water, one ton heavier. It could be raised by hand power to a height of 7¼ feet, which left room enough beneath for barges. The width was 12 feet and the lattice girders were 40 feet long, though the water opening was only 14½ feet. It was the first bridge on the site, and has since been replaced.

After completing the Erie Canal in 1825, elevated fixed bridges similar to those in England and France, had been used, with approach grades of 7 to 8 per cent., the grades being afterwards reduced and lengthened, with slopes not exceeding 4 to 5 per cent. A few swing bridges with center piers were then tried but none of them were satisfactory. The need of more efficient ones became evident, and in 1872 Squire Whipple began his investigations for commodious ones. He found that a center pier was too great a hindrance to navigation in a canal only 60 feet wide, and to place a turn table on one side, would obstruct valuable wharfage and business property. He therefore designed a vertical lift bridge on which a patent was granted to him in 1872. The first bridge at Hotel Street, Syracuse, was completed in 1874, and in 1907 was still in service. The platform, 60 feet long and 18 feet wide, was the only lifting part. It was suspended by rods 10 feet apart, from the fixed overhead trusses supported on end towers, the rods moving up inside the hollow columns of the trusses. The bridge crossed the canal and tow path, the total length of trusses being 72 feet. The counterweight consisted of twelve long cast iron boxes nine inches square, filled with pig iron, six of them hanging on each side, and weighing when empty 800 pounds. The whole moving weight, including counterweight, was 20 tons. A tread wheel 9 feet in diameter was used for raising two weights, one of which was for lifting and the other for lowering the bridge, both of which merely to overcome friction, were twice as large as actually needed. Their movement was regulated by a ratchet wheel like that on a clock. The rope sheaves were 3 feet in diameter for ¾-inch rope, turning on 2¼ inch axles. In the same year (1874) a patent was granted to A. J. Post of Jersey City for a "vertical sliding bridge guided by columns at the four corners, operated by flexible connecting belts between the towers, driven by a windlass and crank." It was counterweighted by heavy blocks hanging in the towers.

Many other lift bridges began to appear in the principal towns along the Erie Canal, among them being the Allen Street lift at Rochester (1878), which was somewhat similar to that at Utica, having overhead girders on corner towers with a suspended counterweighted platform. Instead of hand power, it was operated by hydraulic motors, which transmitted power to an overhead shaft with pulleys. Other similar ones were soon afterwards built in the same city.

Benefiting by the experience of American engineers, a lift quite similar in principle to those at Utica and Rochester was erected in 1878 at Calcutta, India, with a span of 116 feet over a tow path and 110 feet waterway. The principal difference in the designs was in the corner towers, which at Calcutta were of stone, giving a much finer and more substantial appearance than the lighter ones of metal used in America. The two lines of trusses were 18 feet deep, and from them, a platform was suspended which could be raised about 13 feet, providing a head room of 20 feet at high water. The counterweight was two tons heavier than the suspended platform causing the bridge to rise and remain open, but the addition of about 4 tons of water to the platform tanks reversed the overbalance and caused the platform to descend, the required overbalance being just enough to overcome the friction. In this respect it was similar to the one of 1873 over the Royal Canal at Dublin. It carried a single line of railway and cost $51,500., the maintenance cost being $450. per year. W. D. Bruce was engineer. Another very fine European design appeared in 1883, the work of J. Pitt Bayley, for crossing the Thames near the Tower of London. The plans showed four deck arches of 175 feet span, and a centre lift between a pair of great metal ribs, the clear width and height of the open passage being 70 and 90 feet respectively. Its width was 54 feet, and length 880 feet, the estimated cost with machinery and approaches being 500,000 pounds sterling.

In the same year (1883) the city of Rochester erected another hydraulic lifting bridge over the Erie Canal, at Lyell Ave. quite similar to the one of 1878. The platform was 78 feet long, 18 feet wide with a projecting 5 feet walk at each side, and the overhead bridge spanning the canal and tow path at one side on a slight skew, was 94 feet long. Another of 1884 over the canal at Syracuse, carries two tracks of the West Shore Railway, and it is on a skew, having a length of 104 feet, but it is different to the last, in that the whole bridge rises and not simply the floor. The trusses are 23 feet with double web systems, and are suspended by wire rope passing over sheaves 7½ feet in diameter. The counterweight boxes are

6 feet by 6 feet by 9 feet, filled with pig iron, the weight of the bridge being 146 tons and counterweight 140 tons more. Previous to this time, the floors were the only lifting parts of railroad lift bridges on the Erie Canal. The towers of the last bridge were 36 feet high, and the span can be raised 13 feet between them. Albert Lucius was engineer. The Salina Street hydraulic lift bridge near-by is similar to the one in Utica, with a crossing angle of 56 degrees, and a span length of 83 feet. It is 25 feet wide, with two 6 foot walks, the floor weight of 60 tons being counter-balanced by semi-cylinder troughs filled with pig iron, suspended by eighteen wire ropes three-quarters of an inch in diameter, over 24 inch pulleys, the floor being capable of rising 9 feet.

The most elaborate system of navigable inland canals anywhere in the world is in France, where not less than 3,000 miles of such waterways are operated under government direction. But, as previously described, France and England generally used fixed overhead bridges with graded approaches, instead of movable ones. Departures from the usual custom were, however, introduced in France at the cities of Paris and Dijon, a very attractive little bridge being completed in 1886 in the reconstruction of Bassin Villette-Canal St. Denis—in Rue de la Crimee, Paris. A lift bridge was preferred to a rotating one, as the tail end of the swing span would have interfered with existing approaches. The canal is 30 meters wide, but the opening at the site is narrowed to half that width, making the bridge 20 meters long, and leaving space at each side of the canal for boats at the docks. The bridge is 7½ meters wide and the maximum lift 4½ meters, but at one side is an elevated fixed foot bridge with a 79 foot span, approached at the end by steps. The main supports are lattice girders and the platform is suspended by means of chains with 2¼ inch links passing over 8 foot sheaves at the top of independent corner towers which are 25 feet high and 27 to 33 inches in diameter. The counterweights descend into pits, the motion ceases when they reach the bottom. It is operated by hydraulic pistons under the center of the end floor beams, and is provided also with hand power machinery, with pinions working on vertical racks placed against the towers. At each corner are safety ratchets which would engage teeth on the towers if the suspenders should fail. Its total weight is 241 tons, and cost 5,000 pounds sterling. It replaced the one of 1868 in which a platform was suspended between brick arches.

Another bridge at Larrey in the city of Dijon, erected 1890 over the Burgundy Canal, replaced an old stone arch of 1800. The span is 32 feet, crossing a 20 foot canal and two tow paths, and it is lifted 4 feet by hydraulic cylinders, the under clearance when raised being slightly less than 8 feet. The pavement is one, peculiar to the canal bridges of France, and consists of old discarded collier ropes of 1½ by 7 inch flat manilla, laid crosswise over the plank flooring. It is said to wear well, but absorbs a lot of water and causes the weight to vary, seriously affecting the counterbalance. At each end are steps leading up to platforms from which the bridge is accessible when raised, so that predestrians may cross at all times.

A highway bridge 184 feet long in three spans, crossing an arm of the Danube at the Alt-Ofen Dockyard, has a centre lifting span of 68 feet. The road is 17 feet wide and the lattice side girders are 7 feet deep, moving between braced metal towers at each corner, which extend 28 feet above the floor. The counterweight of 44 tons is hung by chains over pulleys, and the whole can be raised 13 feet by a windlass and hand power near the span centre, giving a clear headroom of 42 feet above low water. It was erected under the direction of Peter Remel, and cost 5,648 pounds sterling.

During the year 1890 a design appeared in Europe for a long bridge with a succession of cantilevers, in one span of which a lift bridge replaced the usual suspended part. Towers were supported above the deck on the ends of the adjoining cantilever arms, and the counter weights hung inside of the two near-by river piers which were 60 meters apart, similar designs with bascules instead of lifts, being patented in America, some years later. In the same year a patent was granted in the United States to J. F. Alden, for a vertical lift bridge with counter-weighted platform hung by rods, the whole being worked by electric motors.

The greatest impetus to the design of movable bridge in America began in 1892 with the competition for a bridge over the channel at Duluth, one of the twelve designs submitted being a patented one by Dr. J. A. L. Waddell for a lift bridge of 250 feet span, rising to a clear height of 140 feet above water, the total estimated cost being $125,000. The trusses were shown 25 feet apart for a line of steam railway and two walks, and outside the trusses were 13 feet roads on cantilever brackets for carriage and trolley travel. The suspended weight was about 500 tons, which was counterbalanced, making the moving mass 1,000 tons. Provision was made for raising and lowering it again by electric power, all in the space of five minutes. Sheaves were 15 feet diameter for forty-eight 1½ inch ropes loaded to only one tenth of their capacity. Towers were not connected at their tops as were those of Cologne, Newport and Antwerp, but stood independent of each other. The prize in this competition was awarded on a double retractile design, but as its cost was excessive, the lift bridge was recommended and accepted, though a bridge of another form was finally built.

On June 30, 1892, the South Halsted Street swing over the East Fork of the South branch of Chicago River in Chicago, completed twenty years before, was demolished by collision with a steamer, and as it was a principal thoroughfare, immediate action was taken for its restoration. Encouraged by the favor shown for a lifting bridge at Duluth, the engineers of that project submitted to the city of Chicago a modification of their former plans, which were accepted, and a contract was awarded to the Pittsburg Bridge Co. on a tonnage basis and estimated quantities, revised plans being prepared by the engineers in less than thirty days. The length of lifting span is 130 feet, crossing a channel of 118 feet on a slight skew of 10 degrees. Trusses are 40 feet apart on centres, leaving a clear roadway of 36 feet, outside of which are 10 foot walks at-each side, making a total width of 60 feet. It was proportioned for a live load of 4,500, and a dead load of 4,000 pounds per lineal foot. The towers at each side are 40 feet square at the base and 200 feet high, the top of pole being 217 feet above water. Rear tower legs have adjustment to provide against any possible settlement of foundations, each leg having a ball and socket bearing with 10 inch screws. Comparison made at Duluth showed that no saving would result from using an elevated fixed span, with suspended floor, and the whole span is therefore lifted 140 feet, leaving a clear under height of 155 feet above water. It rises at a maximum velocity of 4 feet per second, the whole weight of bridge and platform weighing 290 tons, being suspended by thirty-two wire cables, 1½ inch diameter, eight at each corner, the power for moving being applied by a seven-eighth inch wire rope. The suspension cables pass over 12-foot sheaves turning on 12-inch axles at the top of towers, and are balanced by cast iron counterweight blocks 10 by 12 inches by 9 feet, moving between vertical angle guides, the whole weight of moving parts being 600 tons, the cables and counterweight chains weighing 20 tons. Beneath the floor are four water ballast tanks having a capacity of 19,000 pounds, for the purpose of regulating an exact balance, and in case of failure of the machinery, the bridge can be operated by water-weight supplied from a reservoir on the top of one tower, filled by pumps in the engine room, all water tanks having steam coils to prevent their freezing. The original design called for the use of two 65 h.p. electric motors, but the city of Chicago required a steam engine plant of 115 h.p. instead. As a steam plant in the towers would have caused too great vibration, the engine room was placed under ground. The cost of the steam power operation and maintenance, however, was found to be excessive, and in 1907 electric motors were substituted for steam. Operation by steam had required the services of three engine men, two signal men, four police and one coal shoveller, or ten men all together, their combined wages being $1,000 per month. In addition to this there was $170. per month expended for coal, the boilers being kept going at all times, whereas the cost of electric power for intermittent service proved to be only $50. per month, with the services of only one tender while two had formerly been needed with steam. Altogether the change to electric power resulted in a saving of $3,240. per year in the operating expenses. The bending of the cables consumed in itself no less than 6 h.p. The comparison just given, is, however, hardly fair, for it was found that 26 tons of sand that was placed under the pavement to crown the road, had not been counterweighted, and this had to be lifted at each operation, in addition to overcoming inertia and friction. Buffer cylinders 12 inches in diameter and 4 feet stroke are provided, glycerine being used to avoid freezing, but the upper bumpers are ineffective as the over head girders where they strike the tower framing have for several years been bent and battered, greatly injuring the appearance.

The itemized cost of the bridge is as follows:—

Substructure	$84,600
Superstructure	81,400
Machinery and engines	50,000
	$216,000

It is claimed by the designer that the bridge could be reproduced at a cost of $50,000 less than that of the above figures, while Mr. W. W. Curtis, the resident engineer in charge, reported that it need not cost again more than $175,000. The use of steam power with engines greatly increased both first cost and maintenance, though in any case the lifting of a whole span to so great a height would consume a large amount of energy. The weight of metal in the span is 250 tons, and the whole weight with counterweight is 675 tons. When inspected recently by the writer, it had no street gates or guards of any kind.

Soon afterwards (1894) the same engineers made plans for a somewhat similar bridge over the Missouri River at Kansas City, using the piers of the proposed Winner Bridge which had been abandoned. Piers were to be cut off 52 feet, making it a low level bridge, and provision was made for two railroad tracks on each deck with trusses 32 feet apart, and double wagon-ways and walks on the upper deck, the total width being 65 feet. Metal towers are pierced above piers No. 4 and 5 near the south side, with an elevated fixed span, and suspended lifting floor weighing 925 tons, all of which is counterweighted at every panel with cast iron blocks supported by one hundred and twelve 1¼-inch steel wire cables, over fifty-six cast iron sheaves 5 feet diameter. The deck can be lifted 45 feet and can be worked by eight men. The hangers which support the lower deck will rise through the main posts of the fixed overhead span when the deck is lifted, as was done on those over the Erie Canal in 1874.

In 1894-95 several new lift bridges were placed over the Erie Canal at Rochester and Syracuse. Two adjoining overhead fixed bridges at Rochester were removed in 1875, and a single swing substituted, but in 1889 it was replaced by two lifting spans. Bridge service on the canal was still unsatisfactory, and in 1894, before rebuilding the West Main St. bridge at Rochester, the state of New York sent a representative to Europe to investigate similar conditions there, special attention being given to the bridges in Holland where canals are abundant. The old Dutch Portal bridge with overhead balance beams was found to be the prevailing type, though some of the newer bridges were being built as double bascules. Returning to America, this representative reported quite fully on European bridges as he found them, and improvements that were appropriate for American canals were adopted. The Emerson St. lift at Rochester, finished 1895, was then the longest span over the canal, the distance between end columns being 112 feet, and the floor only is raised, like Whipple's first one of 1874 at Utica. A very serious accident happened to another one at Rochester in November 1896 when the whole movable structure of the Caledonia Avenue bridge fell from its highest position upon a passing canal boat, fortunately without loss of life. It was to prevent such an accident as this, that safety appliances were added to the Ourcq Canal lift at Rue de Crimee, which was previously described. On March 7, 1898, another bridge over a dry bed of the Erie Canal at Whitesboro St., Utica, failed, killing one person. It weighed about 50 tons and is said to have been built forty years before, but had been condemned and closed for a year. It is interesting here to note the heroic measures used at Watervliet, N.Y., to meet operating expenses. The draw was raised and left up until the two adjoining towns paid the bridge tenders' wages which were a year in arrears.

The second important event in America to cause progress in the design of movable bridges was the competition for one over Newton Creek at Vernon Avenue in 1896, when among many others, a lifting design was submitted by F. S. Williamson, similar to that at Halsted Street, Chicago, with an estimated cost of $200,000. A contract was awarded to the King Bridge Company for its construction at a price of $418,000, which agreement was afterwards cancelled.

No lift bridges worthy of notice had been erected or proposed in other countries since the completion of those in France in 1886 and 1890, until 1896, when a small one was placed over Murray River at Swan Hill, Australia, between New South Wales and Victoria, with a 14 foot highway and a 58 foot span. The whole bridge weighed 34 tons and cost only $44,500, and is operated by one man hand power. There are no masted ships on the river and the maximum lift is, therefore, only 30 feet. The design was the work of Mr. Percy Allen.

In the four years following 1899, five other lifts were placed over the Erie Canal at Utica, Lockport, Rochester, and Canajoharie. On the Schuyler St. lift at Utica (1899) with a span of 84 feet, the floor only is raised. The Lockport lift, 111 feet long and 32 feet wide, is worked by hydraulic power from the city mains under pressure of 90 pounds per square inch, the piston rod being attached to a cast steel rack gearing with an 8 inch pinion, all machinery being below the floor, but it is equipped also for hand power. The towers are 24 feet high, supporting cables of cast steel rope, supporting the cast iron counterweight. One at West Avenue, Rochester (1902) with a span of 139½ feet, is the longest over the canal, and air-tight pontoons are used instead of counterweight, similar to that used the same year for a direct lift over the Elbe-Trave Canal at Launenburg, Germany, and at Wattrelos, two years later. Other similar bridges are at Plymouth Avenue, Rochester, 1903, and Church St., Canajoharie, 1904. The lift bridge over a street subway at Friedrichstrafse, Dresden, is quite different from the usual forms, the upper road being lifted about 5 feet by means of levers to which segments are attached, on which hand-operating pinions are worked by winches.

Another important American waterway, the Miami and Erie Canal, which is used for barges only, had for many years been equipped with automatic closing swing bridges, mostly of the "Smith Bridge Co." type, but in 1900 a new form was erected at

Middletown, Ohio, 34 feet long and 66 feet wide, crossing the canal and tow path, the floor being raised about 9 feet for the passage of boats. The moving part weighing 46 tons, is balanced by two counterweights of 23 tons each, lifted by an electric motor beneath the floor, the maximum armature speed being 1,100 revolutions per minute. Another, and very economical design of lift bridge for small waterways, was prepared by the writer in 1904 in the competition for one to cross the same canal at New Bremen, Ohio. The bridge has a 28 foot roadway and two 6 foot walks, with plank floor and steel joist. It consists of an ordinary deck plate-girder highway bridge suspended and counterweighted by means of wire ropes passing over sheaves at the four corners, the counterweights moving up and down inside the towers. The fixed end of the rope is attached to the overhead lattice girder, and produces bending therein. The bridge is raised and lowered by means of four pinions working on racks attached to the corner towers. These pinions are connected through a series of shafts and gears to a 10 h.p. electric motor placed beneath the floor, the motors and machinery being enclosed and protected from the weather. For oiling or inspection, it can be reached through a movable panel in the floor. The controller is placed against the railing and is likewise enclosed, electric current being taken from the street wires. The quantities of material in the superstructure are as follows:—

Riveted steel work	37 tons
Machinery	5 "
Counterweight iron	20 "
Steel joist	6 "

Electric motor and equipment.
Lumber, 6,000 feet b.m.
Estimated cost, $5,300.

Generally, all forms of lift bridges require expensive counterweights. In this case, the cost of counterweights alone is about 20 per cent. of the entire cost of the superstructure. In nearly all other forms of lift bridges, the cost of counterweight greatly exceeds this amount. In South Halsted Street lift bridge at Chicago, the total weight of metal in the structure is 675 tons, and of this amount, 290 tons, or 43 per cent. is counterweight. This expensive feature applies not only to direct lift bridges, but also to all forms of bascule bridges, which are counterweighted to a greater or less extent. Swing bridges over canals with only one waterway, have either one half of the bridge over the land where it is not required excepting for a counterbalance, or have one short arm loaded with cast iron or concrete, either of which arrangements are expensive. The retractile draw similar to that at Summer St., Boston, which rolls back on a track at an angle of 45 degrees to the canal, is likewise expensive, inasmuch as a large part of the bridge must be built over the land, in order to give room for mounting it on trucks. The trucks and track, and the excavated recess for the bridge when it is rolled back into its open position, all add to its cost. Swing bridges with small roadways, such as commonly used over waterways, are not suitable for wide roadways with sidewalks. The ordinary drawbridge over the Miami and Erie Canal through the rural districts, has a roadway 12 to 16 feet in width, and is a bob-tail swing. It is opened by the pressure of the boat against it, and after the boat or barge has passed, the bridge swings back again automatically into its closed position. A bumping timber backed with springs is bolted to the side of the bridge to receive the blow of the barge as it strikes the bridge and opens it. These bridges are very common along the canal, and are satisfactory for rural districts and light travel. But where wide roadways and walks are needed to accommodate city travel, they are then no longer practicable.

The normal width of the Miami and Erie Canal is 50 feet, allowing three boats each 15 feet wide, to pass each other. But at crossings, the canal is frequently narrowed to about 32 feet, and the cost of the draw bridge reduced accordingly. The estimated costs of other forms of opening bridges for the same location, are as follows, and in each case the estimate is based on providing a fifty foot clear waterway. A double leaf bascule with leaves meeting at the centre, and towers at each side, with a platform 60 feet long, would cost $5,700. A single retractile draw, similar to that at Summer Street, Boston, would cost $7,300. In this case the length of platforms required is 75 feet on one side and 115 feet on the other. A bob-tail plate girder swing, with sand counterweight, would cost $5,400. The length of platform in this case would be 90 feet. A revolving truss swing with equal arms, and a platform 140 feet long, would cost $6,700. Comparative estimates are therefore as follows:—

Tower direct lift bridge	$5,200
Double leaf bascule	5,700
Single retractile draw	7,300
Bob-tail plate girder swing	5,400
Revolving truss swing, equal arms	6,700

The bridge was designed to open by electric power in one minute, and it appears to fulfil all the requirements for the given location. Gates should be used at each end of the bridge, to be lowered or closed before the bridge is opened.*

The forty-one movable railroad bridges in New York State were examined in 1907 by engineers, under the direction of the State Board of Railroad Commissioners, with a view to making such changes as might be necessary to insure public safety, and the conclusions and report of this board contain many valuable provisions. (*Engineering Record*, July 10th, 1907).

Several comparatively small lifts in other countries are those at Haslar, Nyasaland, and Edinburgh, all other ones of any importance being in America. That over the entrance to Portsmouth Harbor, at Haslar, England, is a small affair of less than 28 feet span, with towers framed in reinforced concrete, though the floor, which is only 7 feet wide, has steel frame. It forms an opening through the

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*Lift Bridges for Small Waterways. H. G. Tyrrell in *Electrical Review*, Dec. 31st, 1904.

harbor jetty and is probably the only one of its kind. A lift over Shire River—a branch of the Zambesi—at Nyasaland, designed by Sir Douglas Fox, has a 100 foot opening, and a clear height above water of 30 feet. The lifting span rises between disconnected towers, supporting the sheaves, and when open, the counterweight descends and lies across the track, forming a substantial barricade. Openings are of rare occurrence, and hand power only is supplied, so it can be opened in 25 minutes by eight men. The weight of steel in the lift span is 55 tons, in tower 31 tons, and in counterweight shells 8 tons. The towers stand on 30-inch cast iron cylinders. The small lift bridge over Union Canal, at Fountainbridge, Edinburgh, has a 25-foot road and steel trough floor. The canal is only 13 feet wide, and the maximum lift is 8½ feet. It has an elevated foot walk at one end, reached by steps, similar to the bridge at Dijon.

A patent was issued in 1908 to Eric Swenson of Minneapolis, for his "gyratory lift bridge" designed for crossing the Narrows at Lake Minnetonka, the counterweight being so placed as to keep the centre of gravity in the centre of rotation, and the towers were to be covered with ornamental iron.

Other important designs for direct lift bridges during the last three or four years are the work of Waddell and Harrington, civil engineers, several patents having been granted to them during the summer of 1908 for bridges at Keithsburg, Chicago, and Portland. One for the Iowa Central Railroad over the Mississippi River at Keithsburg, will not contain a draw of the usual form, but a novel lifting arrangement instead. Several spans are so arranged that towers can be placed at their ends, with their rear legs on the adjacent fixed spans. The 230 feet intermediate span between the towers can then be lifted 45 feet, thus providing for a shifting channel. Comparative tenders received, showed the arrangement to cost about $39,000 less than an ordinary swing. Three other lifting spans over Calumet River, Chicago, were begun in January, 1910, one being a four track bridge for the Lake Shore and Michigan Southern Railway, the other two, double track bridges for the Pennsylvania Railroad, all having skew spans of 210 feet, crossing a waterway of 140 feet. The concrete piers will go down to rock and the moving span will rise to give a clear height of 120 feet above high water.

The lift bridge at Hawthorn Avenue, Portland, Oregon, contains a span 245 feet long, which is capable of rising 110 feet, leaving an under clearance above high water of 165 feet. The trusses are 23 feet apart with curved upper chords, and floor beam overhanging 19 feet for car tracks, making a total width of 63 feet. The total weight of lifting span with floor and machinery is 885 tons, which is counterweighted with concrete blocks 21 feet by 37 feet by 6 feet 10 inches. Towers are 170 feet high, each one weighing 128 tons. The cost of substructure is $100,000, and superstructure $350,000. The other lift at Portland, for the Oregon Railway and Navigation Company is the largest of the kind ever attempted and adjoins a swing bridge built from plans by George S. Morison in 1889. It contains two decks, the lower one only, being lifted

52 feet for ordinary craft, which includes about 90 per cent. of all the river travel, although the whole span and both decks can be lifted between the towers for masted ships, leaving a clearance of 135 feet. The approach trusses are through spans with a railroad on the upper deck, and highway 70 feet wide on the lower one, which is locked down when in service. The highway is paved with blocks on plank supported on cross ties, all wood being creosoted. Its total cost is reported to be $1,650,000. The method of providing two decks, both of which are movable, is somewhat similar to that used in 1891 for the elevated railroad at Liverpool, England, where the double bacsules of the lower deck are lifted for small boats, while for larger ships, the whole bridge with lower platform suspended from the upper one, can be revolved open on turntables at each side. Other small lift bridges are in Idaho, Washington, and Arkansas, and another over the Miami and Erie Canal at Mohawk Place, Cincinnati.

It appears therefore, that the chief progress during seventy years, in the design and construction of direct lifting bridges, has been in the use of steel towers instead of cast iron and stone, and in the substitution in some cases, of floating buoys instead of counterweight, a method which was successfully used by M. Vescovali in 1893, in the Tiber River bascule near Rome. Compensating chain weights have also been used in some recent works, modifications of those invented by Poncelet, and used on bascules in France, prior to 1847. In only one case—at Kansas City—has the length of lifting span exceeded 300 feet, as proposed by Oscar Roper, of Hamburg, in 1867.

PATENTS AND THE ENGINEER*

Recently the University of Toronto Electrical Club was favored with a short address upon a subject of exceedingly live interest to the young engineer. The speaker, Mr. J. E. Maybee, Toronto, is very widely known for his authoritative knowledge of protective measures surrounding inventions and the transformation of an idea into a patented commodity.

The main purpose of the address was to point out to prospective inventors the proper course to follow if they wished to avoid the more common pitfalls which beset the inventor's path. The great inventions, outside a few lucky hits, are not made by men who sit down with the idea of inventing something, but in response to the stimulus of a known want.

An inventor who succeeds with the least waste effort will follow fairly closely the following order of procedure, which is given substantially in the lecturer's own words:

1st. Find a want, i. e., be sure you have a market. It pays to devote the utmost care to gauging the needs of your public.

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*From a paper read before the University of Toronto Electrical Club, by J. E. Maybee, of Ridout and Maybee, December 8th, 1911, Toronto.

2nd. Be sure you have, or can acquire, a sufficient quantity of knowledge to enable you to direct your efforts wisely.

3rd. Obtain as wide a knowledge as possible of the inventions of others along similar lines. (Some in practice do this just before taking step No. 6).

4th. With sweat of brain evolve a new idea and embody it in concrete form.

5th. Devote every effort to work out your details as thoroughly as possible, so that your device will not only work well, but what is just as important, can be easily and cheaply made.

One of the most fruitful fields for inventors lies in devising means for more cheaply making various articles of manufacture or in devising simplified forms of commonly used articles or machines.

6th. See that you get as good a patent as can be obtained.

In both patents and inventions "Pretty near" is not good enough. In a recent address before the Engineers' Club, of this city, Mr. Justice Riddell pointed out that failure to keep the above maxim in mind led to such disasters as the Austin dam failure, and unless the inventor would court failure he must make "As good as possible" his motto, and he should select professional advisers who will live up to the same rule.

It was pointed out that engineers, as a rule, did not figure largely as patentees, the exceptions being those specially employed by large concerns to perfect their goods or machinery.

The main reason given for the lack of inventiveness of the engineer was the necessary conservatism of his procedure in his work, whereas the disposition of the typical inventor was to exhibit a contempt for authority and tradition.

A strong plea was made to the engineering student to acquire as broad a general culture as possible and to cultivate the imaginative faculty, which in essence, is the same in the artist as in the engineer, and which is one of the most useful and prominent characteristics of a successful inventor.

TESTS ON STEEL COLUMNS

L. R. Wilson, B. A. Sc., '09

In the spring of 1911, a series of tests was conducted in the Strength of Materials Laboratory of the Faculty of Applied Science on several steel columns of a size comparable with many in ordinary commercial service. Fig. 1 gives the data for two columns. It will be noted that the radii of gyration are about equal in either direction, although that in the plane of the lattice is somewhat smaller. One of the objects of the test was to compare the efficiency under a comprehensive load of the two types of lacing illustrated. Batten plates are frequently met with on tension members; hitherto practice has adhered closely to the familiar lattice-bar type of column. The test-pieces were made as large as the capacity of the machine (100 tons) seemed to warrant, and the details were designed in proportion excepting that very heavy end-plates were used to ensure that failure when it occurred would be in the body of the member.

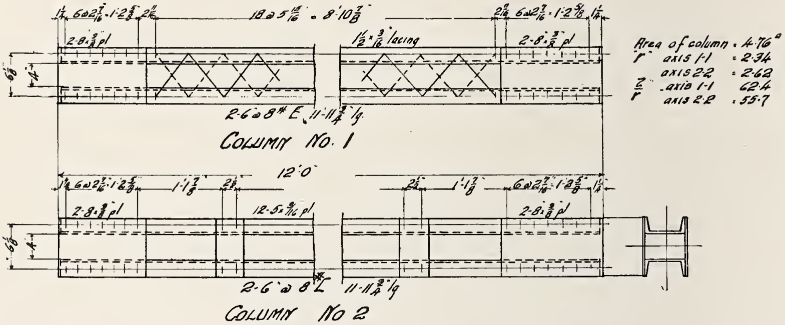


Fig. 1—Column Data.

Inspection of the columns on their arrival showed workmanship to be good, all rivets were tight and well driven, and the back-to-back of channels and rivet-gauges agreed well with those required on the shop drawing. The lattice-bars had, however, been taken from stock, and were heavily corroded under the paint. One bar had been bent about one-quarter inch during shipment, but was partially re-straightened. Also, on the latticed column No. 1, the channel overran in length on one side of the lower end as placed in the machine, so that it was in bearing directly instead of receiving its load by shear on the rivets in the end-plate. These points are noted here, not because they seemed to affect the results, but to show that the columns were not ideal for test purposes. For that very reason, however, the results are more applicable to everyday practice where similar irregularities are more or less common.

It was the original intention to carry out a complete series of tests for central and for eccentric loading, with eccentricities both in the same and in opposite directions at the two ends, the obliquity in the latter case producing the most serious lattice stresses. It was intended to vary the eccentricity from one-quarter inch to one inch, thus gathering a mass of data from which to make deductions. Unfortunately, the regular term work and the nearness of the examinations together with the necessary care and slowness in taking observations, compelled the narrowing down of the program materially. A severe handicap was also felt in the necessity of adapting for these tests measuring devices designed for specimen tests, but after patient experimenting some very regular results were obtained. Longitudinal compression was measured over a length of ten feet and on diagonally opposite corners of the column by micrometer screws, making electrical contact. Lateral deflections were measured at the mid-point on the column by means of finely divided steel scales and a strong magnifying glass. Tightly-strung fine wires enabled the deflection to be easily read to 0.005 inches. To measure the strains in lattice bars a special arrangement was devised which multiplied the strain in a distance of four inches by two. Using a sensitive micrometer screw with electrical contact, very fine readings were obtainable. A great deal of time and study was spent on the question of observations, and it was found that but limited resources were available in the way of devices likely to give reliable results. It is obvious that on a small column the placing of suitable instruments to test the various parts demands considerable ingenuity, where the column is placed vertically in the machine, and is not convenient to a concrete floor level.

In the end, the column No. 1 was loaded to 100,000 pounds with an oblique eccentricity of one-quarter inch, then released and loaded centrally until failure occurred. Column No. 2 was loaded centrally only and the test carried to the point of failure. In connection with the question of eccentricity, it is, of course, apparent that, apart from theoretical considerations, it is extremely difficult to judge of the actual accuracy of centering the load. In spite of the utmost precaution, slight irregularities in the column and in the distribution of the load from the machine introduce an element of error which it is impossible to determine.

The general method of setting up the columns is shown in the combined photos of Fig. 2. The load was applied to the column through bevelled bearing plates and flat shoe plates, which permitted of a desired eccentricity being applied Between the shoe plates and the foot of the column was placed a thick pack of coarse blotting paper to help equalize the distribution of the load. There was thus a slight free motion to the ends of the column, but, in view of the long heavy end plates, it is likely that the column acted as one with fixed ends.

Column No. 1 was first set up with a carefully measured oblique eccentricity of one quarter inch in the plane of the lattice-axis. A load of about 50,000 lbs. was then slowly applied and general observations taken which indicated no happening of note. It was considered that this would produce any possible slip or movement of the several parts of the column and bring them into their normal state of service. The load was now run off to about 5,000 pounds,

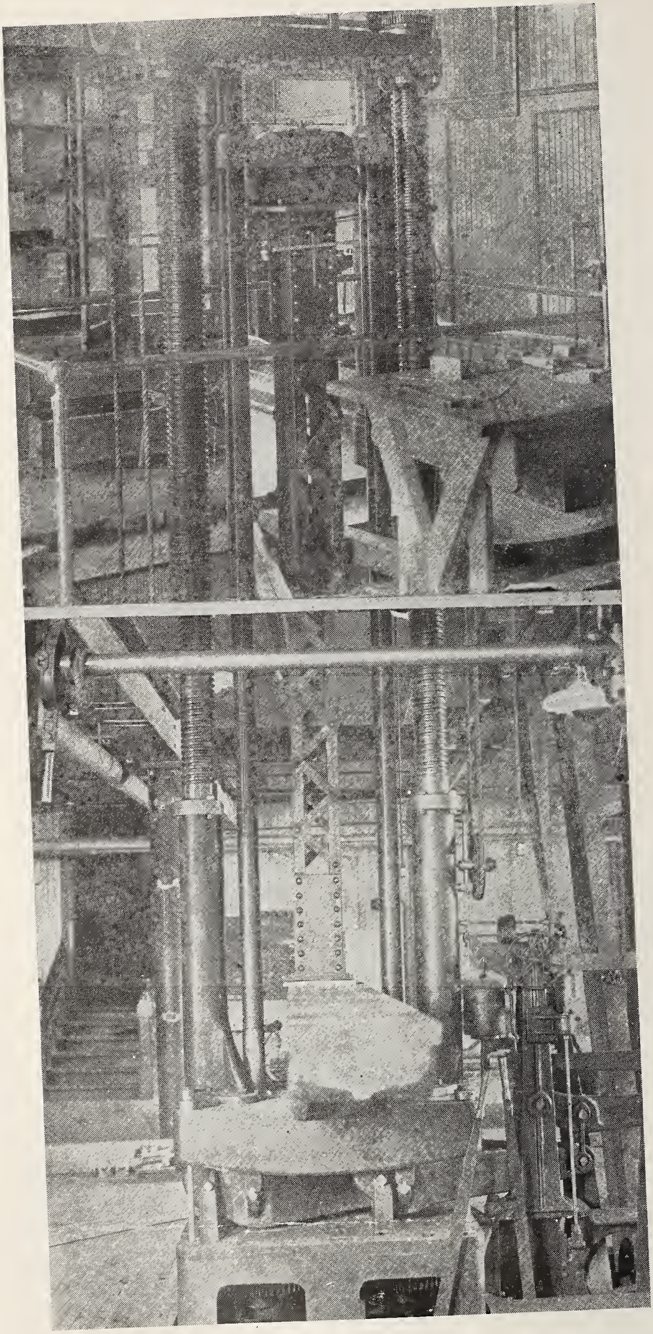
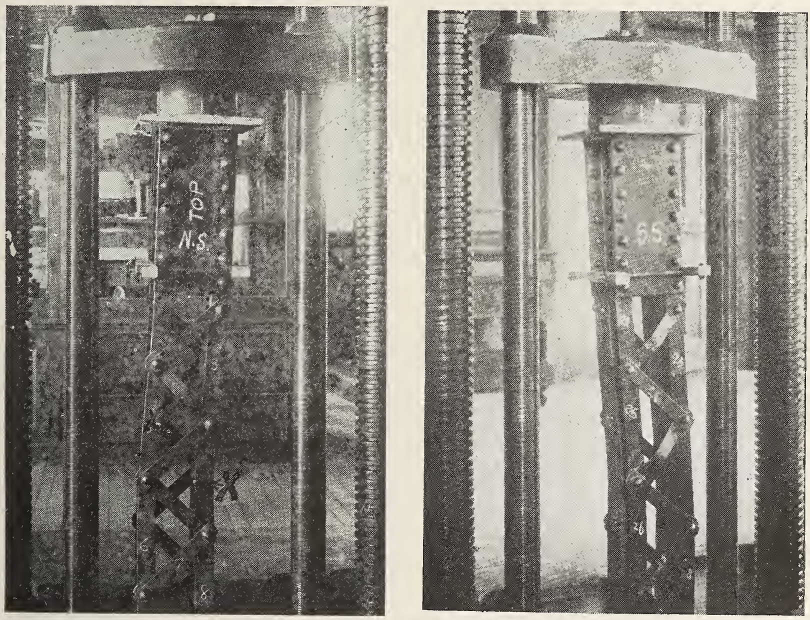


Fig. 2.—Column in position, showing machine bed in lower photo and column head (floor above) in upper photo.

and a series of tests made as follows: An extensometer was securely attached to a lattice-bar or other part of the column and the load gradually increased to 100,000 pounds, readings being taken at intervals of 20,000 pounds. On reaching the upper limit the load was reduced to the initial value and a check reading taken on the extensometer. Although a slight vibration of the machine on releasing the load affected some of the observations, the general agreement was good and in a number of cases was absolute.

The very pronounced feature was that the adjacent bars were all alternately stressed, compression and tension. The end bars were compressed on one face of the column and in tension on the other, at each end. In other words, the lattice-bars acted as the Web system of a Howe Truss and were stressed in perfect accordance with such truss action. Referring to Figures 3 and 4, the stresses in the two top bars in Fig. 3 were —2100 and +1500 respectively, while at the lower end and on the same side the stresses were —2250 and +1700 respectively. The stress in a bar at the middle of the column was —1150. In Fig. 4 the stresses in the two top bars were +1500 and —2100 respectively, just the opposite to those in Fig. 3. These stresses are given in pds. per square inch (+compression, —tension) and are for a load of 100,000 pounds on the column. The maximum stress recorded in the flange of the channel was at the top (Fig. 4) and amounted to 24,000 pds. per sq. in. The maximum lateral deflection observed was 0.105 inches in the



Figs. 3 and 4.—Showing latticed columns at failure.

plane of the lattice and 0.055 inches in a plane at right angles to the lattice axis. Also, all increases in stress and deflection were proportional to the load up to 100,000 pounds. Two points will be noted —that the lattice stresses are quite small and that a distinct deflection took place about both axes.

Finding it necessary to abandon the elaborate series of tests under eccentric loads the column was now carefully centred in the testing machine. The extensometer was firmly placed on an end lattice-bar and measurements of lateral and longitudinal deflections prepared for. The load was applied slowly and steadily, pauses being made to allow of readings at steps of 20,000 pounds. Up to 135,000 pounds the action was quite normal, with no sign of failure. Past this point it was almost immediately observed that the channel was bulging at the points marked by a cross in Figure 3, and an instant later the lattice-bar buckled. This failure was followed instantly by a parallel failure on the other face of the channel (see Figure 4). The operator gave the load at 144,000 pounds but, as the beam had not been perfectly balanced, the point of failure was probably in the near vicinity of 140,000 pounds. The load was run back to 105,000 pounds, when it was evident that permanent deformation had occurred and the column was again loaded. The deformation became more and more marked and the ultimate load was found to be 157,000 pounds.

Figures 3 and 4 show the column in place shortly after failure. Initial failure occurred, as already stated, in the near side of the channel (Figure 3). Figure 5 gives excellent views of the column

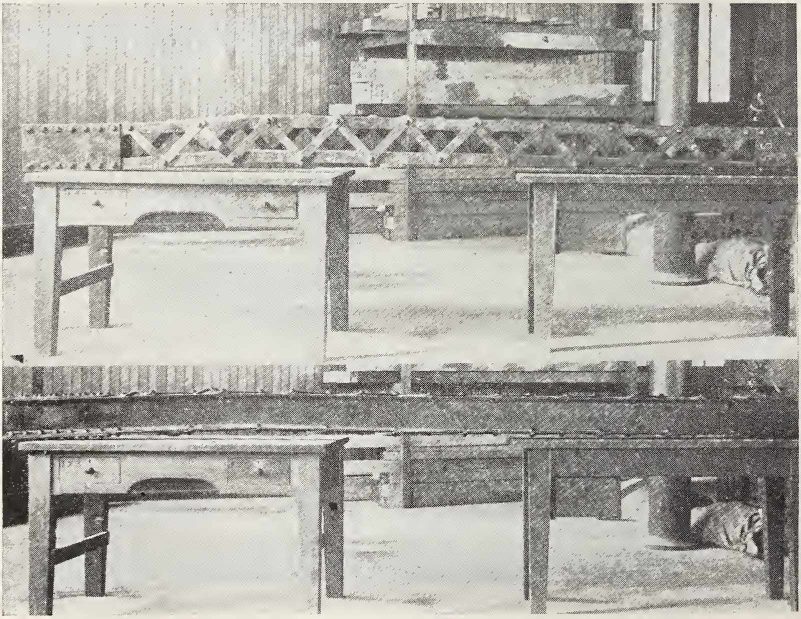


Fig. 5—Combined views of latticed columns after removal from machine.

after its removal from the machine. They show graphically the fact that adjacent bars on each side carry opposite stress. The deflection about the two axes is also conspicuous, that in the plane of the lattice being more pronounced. It is a noteworthy fact that up to the point of failure practically no deflection was found in this latter plane, whereas a steadily increasing deflection took place in a plane at right angles. On failure taking place, however, the buckling of the lattice produced a much greater deflection in the plane of the lacing. Lastly, the point of failure is much nearer to the upper end of the column. Whether this is due to a local fault in the material or to mere accident, is not known. In this connection it should be stated that the injured bar previously referred to was near the other end of the column, and although

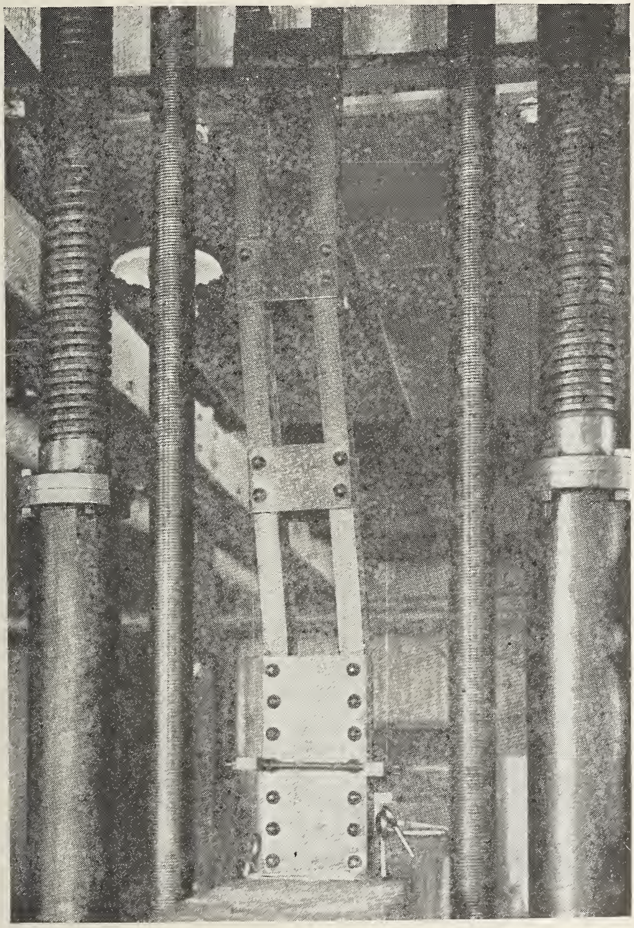


Fig. 6—Failure of column No. 2. Note restraint due to end plates.

watched closely, apparently had no influence on the result. The actual failure may probably be attributed to a combination of direct stress and a high secondary stress due to deformation in the lattice system. This combined stress in the flange of the channel caused failure, as shown, on the elastic limit being locally exceeded. This secondary stress would be greatest at the end of the column, which fact of itself would make reasonable the unsymmetrical failure. Evidently the lattice was sufficiently proportioned to do its full duty as first failure undoubtedly took place in the channel itself. In other words, "every last ounce" of strength was obtained from the column. Whether or no the lattice was economically proportioned is quite another question.

Following the test of the latticed column, a similar test was conducted on column No. 2, that with tie-plates replacing the lattice-bars. Here, for reasons already mentioned, a central load was only applied and in a similar manner to that in the earlier test. Although an interesting field of investigation lay open, it was found impracticable to get any valuable figures other than those giving the deflections of the column. On reaching a load of 100,000 pounds, the column was released and returned to its original state. Up to a load of 140,000 pounds nothing out of the way occurred although there was an apparent deflection. On reducing the load at this point to 100,000 pounds a slight permanent deformation was reached as evidence that the elastic limit had just been reached. On reloading, the deflection in the axis of the tie-plates became more pronounced and increased rapidly until an ultimate load of 163,000 pounds was reached.

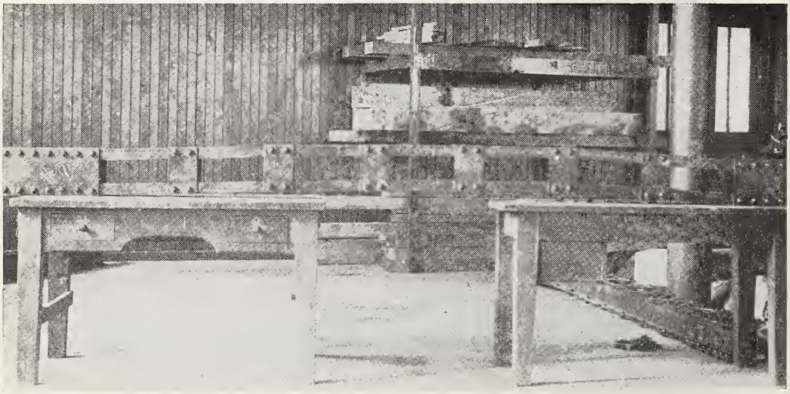
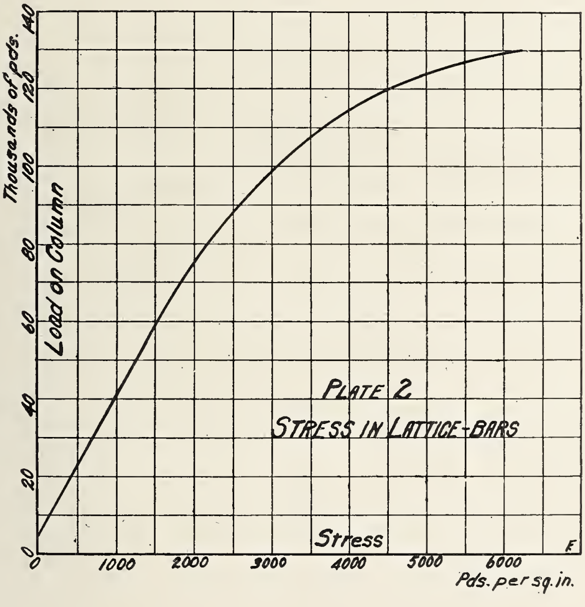


Fig. 7—Column No. 2 after removal from machine.

Figures 6 and 7 illustrate the failure of the column. No local defect appeared, and the eye failed to detect any but the most imaginary buckling in any of the tie-plates. The column deflected with almost perfect symmetry, the buckling length being that between the end plates. The restraining effect of these latter is extremely well marked in Fig. 6, and one also notes here that the tie-plate nearest the end has bodily distorted the channel from its otherwise easy curve. Had the plate been weaker, or the rivets less able to resist the shear due to the torque produced under the deflection of the column, it would seem reasonable to at least anticipate a local failure at this point.

The increment in cross shear between the end-plate and the first tie-plate is considerable and has to be taken by a torque on the tie-plate, producing more or less severe stresses on the rivets. In the lattice-column the continuity of the lattice system is designed to take care of the shear increment. In this type of column it is obvious that the end plate and the first tie-plate should not be too far apart, and that a proper rivet distribution should be provided for the moment to be taken by the plate.

It may be noted here that after failure, examination of the columns showed that the rivets had remained sound and tig and that, while scaling had appeared in several places, no cracks or flaws were visible. Judging from the action of the two columns, each deflected and ultimately failed as a unit from which it may be inferred that the system of latticing used in either case was at least sufficient to fully develop the strength required of it.



It will be of interest to study more closely some of the figures from the tests. In the final test of the latticed column, the stress in the end bar was found to increase as shown in the curve of Plate 2. The stress under a load of 100,000 pounds was found to be 3,400 pounds per square inch; the maximum stress observed was

5,100 pounds per square inch. These stresses seem somewhat inconsistent with those for the case of eccentric loading, but as both eccentricity and unit stress were small, it is probable that incidental factors influenced the results sufficiently to overshadow what would be the truly characteristic results.

Selecting a very common formula for column unit-stresses, $16,000 - 70\frac{l}{r}$, the allowable load on the column is found to be 4.76 x 11,640 = 55,400 pounds. According to the present Quebec Bridge specifications the lattice shall be proportioned for a cross-shear of two per cent. of the allowable load on the column, in this case 1,100 pounds. Assuming a parabolic deflection parallel to the lattice-axis the maximum cross-shear would be represented by $s = 8\frac{car}{d}$ (See Report of Quebec Bridge Royal Commission, page 195). On introducing the suitable values, the maximum shear is seen to be 875 pounds. Now the area of one lattice-bar equals 0.28 square inches, and for a load of 55,000 pounds the unit-stress was observed to be 1,500 pounds per square inch. Thus for two bars we find, for an assumed inclination of 45°, that the cross shear is $1,500 \times 2 \times 0.28 \div 1.4 = 600$ pounds. The deflection was, of course not parabolic, nor was it completely in the plane of the lattice. The figures are, nevertheless, interesting as indicating a safe provision under the specifications for all lattice stress likely to occur.

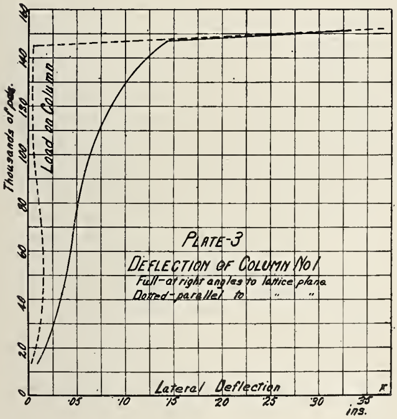
The ultimate load on the lattice column was 157,000 pounds, or 33,000 pounds per square inch; from observation, the yield point was set down at 140,000 pounds, or 29,400 pounds per square inch. Thus for an allowable unit stress of 11,640 pounds per square inch, the yield point provides a factor of safety of 2.45. In the case of the second column the ultimate load was slightly higher at 163,000 pounds, or 34,200 pounds per square inch; the yield point was apparently the same as before at 29,400 pounds per square inch. Here again the factor of safety is 2.5, which is what would be desired in good practice.

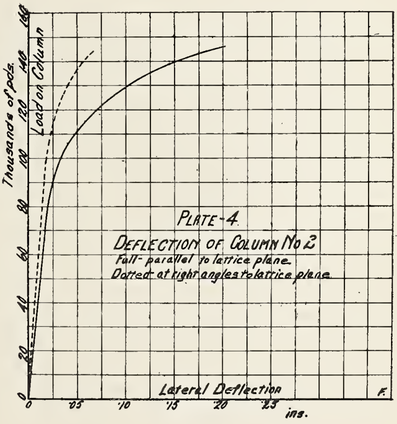
Plates 3 and 4 illustrate the deflection of the columns under the increasing loads. The characteristic features have already been dealt with.

Considering now the relative efficiency of the two columns, it is evident that there is little or no distinction as regards strength. The weight of the tie-plates is slightly less than that of the lattice-bars and there are fewer pieces to handle. The number of rivets to be driven is practically the same in either case. In columns which are of considerable length and with heavy webs, the lattice bars facilitate assembling by drawing the webs together at closer intervals. On the data at hand, one inclines to the opinion that for columns designed for moderate loads both types are equally serviceable when properly proportioned, but that for heavy loads and long columns the end cross-shear becomes excessive unless the system of latticing is continuous from the end to some distance. It is impossible at present to establish a boundary line. Undoubtedly the second column is more elastic and less subject to secondary stress such as is produced by deformation in the lattice-bars. Its more symmetrical buckling is probably natural rather than accidental.

Apparently the details were suitably proportioned in the columns under discussion; there is room for a profitable series of studies to determine the economical size and spacing of tie-plates on a column of such type, thus affording some assistance to the judgment of the designer.

In the preliminary studies it was planned to observe a number of important points. For one thing it was hoped that reliable figures could be obtained as to the stresses co-existing on the inside and outside faces of lattice-bars, plates, and channels. It is well known that the eccentricity of the centres of gravity of the channels from their riveted connection produces distortion, causing a different distribution of stresses to what would be looked for in the ideal case.





While some data was collected it was found quite inadequate to allow of any satisfactory conclusions being drawn. With limited time and facilities it was thought more profitable to concentrate on other lines. Now that the ground has been broken it may be expected that greater facility will be provided by the authorities for the proper carrying on of tests which cannot but be of value to all concerned.

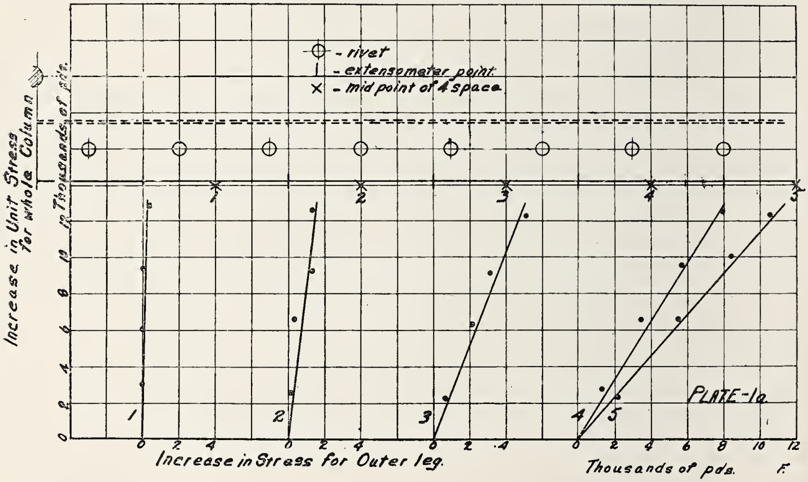
The tests were made possible through the kindness of the Dominion Bridge Co., Limited, Montreal, P.Q., Mr. Phelps Johnson, general manager, and Mr. G. H. Duggan, chief engineer. Arrangements were made through Mr. F. P. Shearwood, chief designer, who took the closest personal interest. In the carrying out of the tests much valuable assistance was rendered by the Dean, as by the various members of the staff in the department. In publishing this account in Applied Science it is felt that, while leaving much to be desired, real progress has been made, and it is hoped that there may be a distinct development along similar lines of investigation in the near future.

ADDITIONAL DATA ON STEEL COLUMNS

J. McNIVEN, B.A.Sc., '10

Subsequent to the tests already described, some interesting results were obtained from a third column, made up of 4 angles (3 x 3 inches) heavily latticed, with sideplates drilled for pin bearings. The purpose of the test was to find the stress in the outer legs of the angles along the full length of the pinplates. In pin-connected bridges, members are often designed with heavy flange angles and cover plates into which the stress must be carried from the pins by means of pin plates connected to one leg only of the angle.

In this column the rivets connecting the pinplates to the angle were spaced 2½ inches apart but the least distance over which the strain could be measured by the extensometer was 4 inches. It would have been of greater value to have been able to test the effect on each rivet over a length not exceeding 2½ inches, but such was found impossible. The instrument was attached at a distance of about ½ inch from the edge of the outstanding leg in each case.

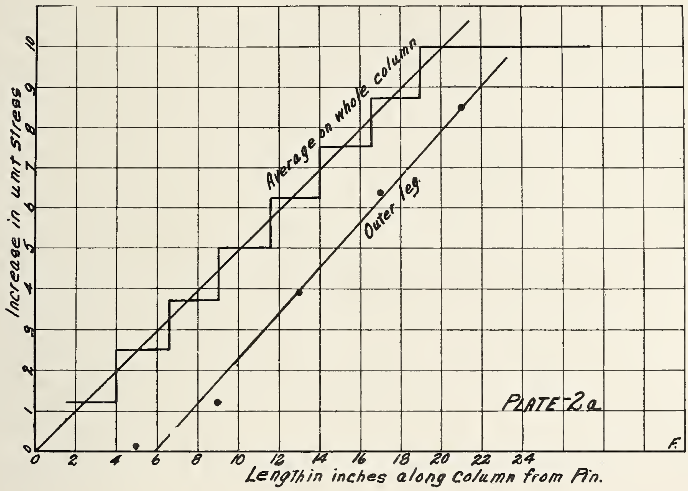


In plotting the curves, the increase in unit stress in the outstanding leg was compared with the increase of stress in the column as given by dividing the load on the column by the area in square inches.

Plate 1a shows an elevation of the end of the column, giving the spacing of the rivets and the spacing of the extensometer point in the test. The vertical ordinates give the average increase in unit stress of the column and the abscissae give the increase in unit stress computed from the readings of the extensometer.

On Plate 2a the ordinates give the increase in unit stress and the abscissae the length along the column measured from the pin centre. For purposes of comparison, values corresponding to an increase in unit stress of 10,000 pounds per square inch on the columns section were selected. From the curves on Plate 1a the corresponding increase was taken for each 4-inch space on the outer leg, these increases being considered as occurring at the mid-point of the 4-inch space and plotted accordingly. In the case of the outer leg, it was assumed in plotting that each rivet took an equal share of the load.

From these two curves, it is seen that the stress gets into the outstanding leg at a distance of from 4½ inches to 5½ inches from where it enters the inner leg, or at less than an angle of 45°. Also Plate 1a seems to indicate a smaller increase in the first two spaces than in the others, which may mean that the rivets near the pin are not quite so heavily stressed as those farther back.



Judging from these results it would seem as well not to be too economical with rivets in pin connections, and the pin-plates should be extended well back to allow the outstanding legs of the angles and the coverplates to get properly developed, thus avoiding an overstress in the other parts of the section.

GARDEN SUBURBS

Model Suburbs and Villages and the Housing of the Industrial Classes.

THOMAS H. MAWSON, HON. A.R.I.B.A.

In the Old World, town planning, in one great respect, takes on rather a different complexion to that which it wears in the Dominions. While the former, where the whole of civilized Europe may be said to be more or less parcelled out into permanent town or country, and changes come but slowly, in Canada, new townships which may ultimately become great cities, are taking their birth every day. As one would expect from this state of things, the model village and garden suburb are much more to the front in England than projects for the creation of new cities, though we are far from being without the latter, for there are many places such as Swindon, Barrow-in-Furness, and many places in Lancashire, which have practically come into being within the memory of living man, and which are now large towns with a permanently settled population and local government of their own.

Still, even in Canada, existing towns will grow, and villages will surround them to provide them with dairy and other country produce, so that if we look a little ahead, we shall be able to see the same process is inevitable in this country, and it behoves us to consider very carefully what has been done in the Old Country to meet the problems thus created, and in particular, to profit by the mistakes which have been inevitable in pioneer work in this as in every other direction.

But before I speak of the smaller suburbs and villages, and the aims and efforts of the public spirited men who have initiated them, I should like to say something of that great and unique experiment in city building which is now being made at Letchworth, about thirty-five miles north of London, known as "The First Garden City."

In its first inception, the scheme was the outcome of a book which first appeared in serial form from the pen of Mr. Ebenezer Howard, a man whom subsequent experience has shown to be possessed of that very rare combination of qualities, idealism mingled with practical common sense and capacity for detail, together with the personal magnetism and knowledge of men and things which enabled him to enthuse others with his conception.

Looking around him at the causes of physical and moral degeneracy of which we see so much in the large cities in Britain, he sought, not for palliatives, but for permanent cures and more still for actual preventatives. His idea was, in its essence, to start a new city on right lines and ensure that it should continue to go right in the future, and so prevent the causes of degeneracy from ever entering it. To ensure this, and, at the same time, to help to maintain rural industries, he suggested that a site of a definite size for a definite number of inhabitants be planned in every detail so that there should be no waste, no property divorced from its original purpose, and thus a slum, and no pulling down and altering, but also large enough for the provision of an agricultural belt round the city whereon small farms for the provisions of dairy produce, generally known as small holdings, might spring up close to the doors of the customer and thus allowing the farmer a good and accessible market, and a householder fresh and newly gathered fruit, vegetables and dairy produce. A further provision prevents overcrowding, and assures that every house shall have proper airspace round it and that, so far as is possible, no house is so placed as in any way to be a disfigurement to the view from any other house.

In order to provide the necessary capital for his scheme, Mr. Howard proposed that all the land should be municipally owned, and none of it sold out and out for building on, but that all rents should be retained in the hands of the promoters and that, from this sum, a reversionary interest should be paid so that, in time, the capital sum invested in the undertaking would be entirely wiped out. The huge income which would by this time be pouring in from the ground rents of the whole of a large city, together with the reversion and resale of leases, would then be devoted to public purposes, so that eventually, it is hoped, the happy denizen of the Garden City will, when he has paid his ordinary rent, have paid also his rates and taxes, and also for many public services such as street cars, libraries, and all kinds of public improvements.

This is, of course, socialism, but socialism of such a constitutional and really moderate description that it has the assent of all political parties, and, in fact, one of the most encouraging features about the experiment is that the permanent officials, notwithstanding the strongest possible pressure on the part of extremists of all kinds, have succeeded in preventing it from belonging to any particular party, but have kept it altogether outside politics of every kind.

It is too early yet to say to what extent the experiment will fulfil the hopes of its promoters, but that it will ultimately be successful there seems no reason to doubt. While, as in all pioneer work, the officials have had to alter their methods and adapt their plans all along in the light of added experience, this has only been in details, and the main principle has remained unaltered.

It would be unfair, at the present stage, to enter into any criticism of details and I would, however, warn those of you who have seen it or may see it at its present stage, against a possible misconception. We are used to seeing a city grow from a small nucleus in the centre outwards. In such a preplanned town as Letchworth, however, the reverse is the case. The main streets and squares in the centre of the town are planned for shops and business houses of the largest kind, which the city will ultimately require when it has reached its fullest development. It is, therefore, evident that these will be the last buildings in the whole of the town to be built, for it is no use doing so until the place has developed sufficiently to make them of use, and so, at the present state, when it is about half constructed, it straggles out in a kind of fringe round this central area in a way which appears very meaningless and devoid of arrangement until one realizes the cause, and knows sufficient of future intention to be able to see how existing and future developments are to interlock.

I have dealt with this largest of English town planning experiments first, because all the others, while very much smaller, are moulded on much the same lines at least as regards some of their developments. One feature they nearly all possess in common, is what we can call a "Co-partnership" scheme. Many working men who are of thrifty habits would like to own their cottages in which they live, but cannot do so because they fear that by so doing, they will hamper themselves if called upon, by the exigencies of their trade, to remove to a different district. The aim of the co-partnership tenants' societies is to remove this difficulty by substituting collective for individual ownership, and allowing the tenant to withdraw his money should he find it necessary to vacate his cottage. Otherwise he has the same fixity of tenure as though the cottage were his own individually, and he pays for it by instalments just as he would if he adopted one of the schemes promoted by building and insurance societies for buying it with the rent. Collective ownership has, of course, the additional advantage of allowing of collective bargaining, and the retention of expert advice thus leading to efficiency and economy.

A comparison of the relative sizes of the chief schemes in England of the kind we are considering is of great interest. At Knebworth, though it is the third largest scheme, the development is still in its first infancy, and everything is yet in the future, while at Ealing, which is one of the smallest, so far as area covered is concerned, nearly the whole of the acreage dedicated to building plots is used up. Harbourne, Ealing, Earswick, Woodlands, Hampstead, Glyn-cory, Port Sunlight, Hyde and Ruislip, are only just commenced, and are in rather a different position to the rest as they will probably become more or less entirely suburbs of London, or what Mr. John Burns calls London Dormantories.

In judging of the success or failure of these schemes, a word of caution is necessary. So far in England they have not been undertaken on a large enough scale to enable us to say how far they will appeal to the average working man or clerk, and if any modification of the methods now used will be necessary to make them so. The tenants of these new suburbs and villages are, more or less exceptional men who have all along revolted at their surroundings, and have eagerly seized the chance thrown in their way of bettering them. Sir William Lever makes no secret of the fact, that, quite apart from his genuine wish that all who work for his firm should be well and generously treated, his garden village, Port Sunlight, pays him as a business proposition, not only because good housing means keen and healthy workmen, but because the scheme attracts a very superior class of artisan or clerk. Even the tenants of the largest scheme of all, Letchworth, are obviously of a very exceptional class, who, many of them, are lovers of a big garden, and delight in the opportunity which the big plots and widely scattered houses give them of developing their own plots in their spare time. It is at present a most marked feature of all these schemes that each tenant shall have a large garden, and I think that, when the idea has gone far enough to absorb the average citizen, it will be found that only a proportion of them will be prepared to take advantage of this.

While I am sure, to put it one way, that this state of things is too good to last, that we shall never find an unlimited number of men with the time and the inclination to develop a large vegetable garden after a heavy day's work, which probably exhausts their physical as well as their mental powers, I do not think that this means that the effort to provide more air space between the houses need end in failure. All that will be necessary will be to arrange matters so that he who wants a large garden, and can make use of it, shall have the opportunity of doing so without having to walk a long distance from his home to an allotment ground, while he who does not want one need not be bothered with it. This can easily be arranged, as, for instance, by building the houses in a hollow square with their backs inwards, and, after deducting the necessary yard space and back approach to each house, laying the rest out in plots to be let to whichever of the tenants desires one. This arrangement would have the additional advantage of keeping the allotments out of sight, and from the very nature of the process of cultivation, they cannot always be kept tidy.

The spacing of houses widely apart, which is practised in all the new schemes, has an artistic, as well as a practical aspect. It is thought that this means will prevent the distressing monotony of the modern suburban street of small property, which, with its exact similarity of every detail in all the houses, down to the long lace curtains and flowerpot in the window, has a depressing effect on the system quite impossible to describe unless one has experienced it. It is, however, necessary, as a writer on town planning said not long ago, to take care that, in the effort to avoid the monotony of rows of houses, we do not create the equally bad monotony of alternate houses and gaps. Speaking generally, this is not, however, a fault of the English Garden Villages. Although the designs of the houses very generally leave much to be desired, there is at least, sufficient evidence of an effort to deal with each house in two-fold capacity of a self-contained unit, and at the same time, a part of the main street vista.

To those of you who do not know England, and the conditions obtaining there, the question will naturally present itself, What are the evils which garden suburb planning proposes to remove, and how far does it succeed in doing so? As an example, one needs but to meditate on conditions at Port Sunlight, near Liverpool, after replanning on garden village lines. I think that there could hardly be a more telling contrast. The plan of the ancient County Town of Lancaster shows how a town grows when left to do so its own way. The plan could not be more involved if it were intended for one of those mazes which people delighted to lose themselves in in the eighteenth century, and which still exist in a number of English gardens. Contrast it with the plan of a small area at Bradford which has recently been laid out and which is very typical of numbers of small plots which are nowadays under development and amazement will be the result.

Let us refer to Bourneville village in comparison with Birmingham, and as Bourneville is practically a part of Birmingham, they are very striking. Some allowance must, of course, again be made here for the fact that the tenants at Bourneville, come, as a whole, from a class of people appreciably superior physically, morally, and intellectually to the average worker who inhabits the slums of Birmingham, but even when all credit is given to this fact, it is not sufficient to affect the figures very appreciably.

These contrasts show the material gain, but besides this, there is the moral, sociological and hygienic improvement. Yet in thousands of cases, men and women are huddled together without even separate sleeping accommodation, and it is primarily to bring people out of such places and make clean decent lives which are worth living possible for them that the garden village movement exists.

It was Mr. Cadbury at Bourneville who first made the attempt to do this on any large scale. Unfortunately, when the idea of starting his village scheme first presented itself to his mind, the importance of planning in advance was not so fully recognized as it is to-day, and thus it came about that Bourneville was planned little by little as it grew, a process which is very evident when one walks over the estate, and which is responsible for most of the shortcomings of what is nevertheless a very remarkable undertaking. The promoter and permanent officials at Bourneville, are, however, quite alive to the defect of haphazard arrangement, and have recently had competitive schemes prepared for the development of one hundred and forty further acres of their estate on a properly preconcerted plan.

Much the same thing has happened at Port Sunlight, the village created by that remarkably many-sided man, Sir William Lever for his work people. In this case, however, the problem was complicated by the existence of a number of small tidal waterways or inlets which so cut up the estate as to make effective planning almost impossible. Nothing could be done to remedy this state of things until the whole of the frontages on the creeks had been purchased by Sir William Lever, and, for a long time, these were not on the market. It is only recently that the last of these became available, and allowed of their being drained and filled up.

As soon as this was done, Sir William promoted a limited competition among the students of the School of Town Planning at Liverpool University, which he had founded, in order to obtain a proper plan for the completion of the scheme, in which the first premium was awarded to Mr. Prestwick, a pupil of the school. His scheme is particularly interesting, as it shows that the students at the Liverpool school of Town Planning are being taught to grasp, and to be able to translate into practice, the principles set before them in their lectures.

Since the holding of this competition, I have prepared, under Sir William's approval, a third plan, carrying the development still further, and, at the same time, suggesting a number of amendments to Mr. Prestwick's scheme which seemed to me desirable with a view to giving a little more cohesion at certain points. It will thus be seen that, in this instance, the estate has been developed in three successive states, which are indicative of the rapid growth and change of feeling towards town planning which has occurred in England during the comparatively short period in which the scheme has been in progress.

The latest plan will make the ultimate effect aimed at much clearer, in having the railway lines form the foreground, a most unusual point of view, and this brings us to another point which I have mentioned in passing before, but which is so important that I may perhaps be excused insisting upon it once more. This is that, instead of turning our backs on the railway, as has always been the practice in England, and planning our town so as to shut it out as much as possible, we should turn our best side to it, our best view and our best impressive vistas, so that persons passing through our town and others arriving at it, shall not gain an impression of dirt and disorder, but of the expression of an awakened civic spirit.

The gain to the city of the future which will result, will be enormous. The railway station is, in many instances, the focussing point of all the town's activities. It is the place which to those visiting the town, stands for the gateway to it, and those who live there, as the gateway to the great world beyond their own narrow, round and daily task, and this, and much more that the railway station stands for, makes it such an important feature in the civic life to the community of each town, that I really believe that its correct placing, with a proper sense of its importance, and the large part it plays in the life of the place will do more to increase the prosperity of the community than any one other feature in the town.

There is another point, however, in which our English Garden Villages have often failed, and which is even more difficult to understand than their neglect of the railway station as a definite factor with a place in the scheme. This is concerned with the placing and arrangement of the shops necessary to the householder, and which, while he is anxious to keep out of sight and sound of, he is very unwilling to be far away from, if we omit the case of those more than well to do people who can depute all shopping to dependants.

Usually, in most of the schemes which I have examined in detail, there has been a central square or market place dedicated to shops and business premises, and this is all, especially when the site of the scheme has been within say, five or ten miles of a big town. A moment's comparison of existing villages and suburbs of any but the poorest class will show that this will not do. Notwithstanding the strong centripetal influence in business matters created by the increased facilities for travel to and from the town and the country surrounding it, which is such a marked feature of modern urban or suburban life and which has greatly altered the conditions of trade in suburban areas, one small business centre for the whole of a garden suburb say three miles across, with perhaps, in addition, a small corner shop there and there, is quite inadequate.

Instead of this, I would have a well thought out arrangement consisting of one rather larger business centre in the middle of the place as usually suggested, and, in addition to it, a series of subsidiary shopping centres at points as nearly equidistant from it and from one another as possible, what I would describe as a "sun and planet" system. This would, of course, allow of all householders being within easy reach of the more necessary domestic supplies, and would have the further advantage of providing each of the tradesmen with his own particular coterie of customers without removing competition to an injurious extent.

There is, however, a further advantage, greater than either of these, for such an arrangement of the business premises of a new garden suburb or city will allow of far more orderly or progressive development than is usually the case. I have pointed out how, at Letchworth, as in other instances, where only one big shopping centre is allowed for, development must go on for a number of years in a straggling and untidy way with no very easily visible purpose in the planning, round a centre yet, bare and undeveloped, and our arrangement of a series of smaller shopping centres round the big one, and showing a definite relationship to it in their planning, will prevent this.

In such a case we shall be able to control development to a far greater extent. Instead of putting the whole of our land on the market at once, we can choose out one of these centres with the property surrounding it and build, instead of a straggling portion of a town, what will be, until it is absorbed in the larger scheme, a self-contained hamlet with its own shopping and other centres of corporate life, so that not only will the place benefit by this system of planning when fully developed, but also from its very beginning. Instead of being unfinished and chaotic in appearance for a long period, it will grow by adding one small and compact unit to another until the two become fused into a part of the larger scheme.

This method of planning, and the study of the growth of cities which it entails, are essential to all town planning schemes, but I have reserved them for notice in this instead of previous lectures, because they apply with such especial force to the garden city or suburb with its very strongly marked aesthetic side.

There is one great danger, however, which we shall have to guard against, in the formation of our first small nucleus of a scheme developed on the lines I am advocating. This is the danger of dedicating the whole scheme to one particular class of society. This is a very real danger in any suburb scheme, and as you will easily see, concentrating the first development may very easily stamp the scheme, in its very beginnings, as the prerogative of one class of society and lead to others tabooing it. I call this a "danger" because I am sure no healthy community can exist which does not contain representatives of all the classes to be found in an average town.

In England we have many object lessons to prove this. On the one hand we have, in the great industrial centres, large towns in which almost every inhabitant is connected directly or indirectly with one great industry, such as cotton, wool, or iron manufacture, while, on the other hand, we have places like Leamington and Bath, where is a most unusual proportion of what are known as the leisured classes. Sociologists who have studied these examples on the spot are agreed that, in such cases, full and healthy social and corporate existence is impossible, and it therefore behoves us to see that, in our newly planned area, provision is made for the needs as well as the customs of all classes. I would therefore, propose that, in choosing the first portion of our garden suburb or city to be developed, we should take care that it is the one which will best allow of this.

Sometimes, and especially in privately owned suburb schemes, it is necessary, in order to give the scheme a start, for the proprietors to themselves build a few attractive houses. These are known as "decoy houses," and, in arranging them, all I have said about giving the place the right social stamp to start with, applies with special force. Unless we are prepared to take this matter very seriously and see that exactly the right houses of the right size, in the right place are built, regardless of their selling value, we had better not attempt to build them at all.

This mention of dwelling houses brings to my mind another outstanding and prominent development of the English Garden City movement. This is the effort which is everywhere being made to provide the working man with a cottage large enough for decency and health, and provided with such facilities for cleanliness and comfort as a full sized bath with a hot water supply, and proper arrangements for the washing of clothes without rendering the whole house damp, steamy and almost uninhabitable by the process, and yet at a price which will allow of an adequate return by means of a rent he can afford. The ideal at present seems to be to produce such a cottage for the sum of £150, or seven hundred and fifty dollars. On every hand we hear much talk of this £150 cottage, but I must say that, notwithstanding the keen interest I have taken in the subject for the ten years or so in which the agitation has been going on, I have not yet seen it. I do not mean that I have not seen cottages built for £150, for I have seen many, and among them a few that are excellent examples of what a workman's dwelling should be, but these have always been built under most exceptional circumstances which could not be reproduced elsewhere, and are therefore useless in helping us to a solution of the difficulties we have to face before the £150 cottage can become an established fact.

In other cases, and these by far the majority, no allowance has been made in the statement of cost for such items as architect's fees, builder's profits, fencing in the ground, share of road-making expenses, sewage disposal, or the like, and, in others, the whole of the supervision has been done by the owner of the property who has combined in his own person the offices of architect, structural engineer, quarry or brickyard owner, builder's foreman and estate agent, and he has been assisted in the work of construction by general handymen who live on the estate and who, in consequence, of security of employment and such perquisites as a cottage rent free, are content to work for wages which are nominally though not actually much less than that of the usual builder's craftsman. Thus, while the individual problem is solved, and the estate owner has the satisfaction of seeing his workmen well and cheaply housed, the greater one remains and we are no nearer its solution.

The National Housing and Town Planning Council of England has taken up this question of the £150 cottage very seriously, and has held competitions in different parts of the country, giving diplomas accompanied by a substantial money price for the best cottage in various classes and produced for sums not exceeding a fixed amount. While these exhibitions have done much to improve and cheapen the planning of workmen's dwellings and to shew the general builder that simple straight forward lines to his elevations give a better result than cheap and meretricious ornament, they have not always received the support, financial and practical, which such a project is worthy of. The many experiments, too, in new methods of building materials, a majority of which must, of course, prove unsuccessful, has tended to disparage the whole project in the eyes of the public, for the average man does not understand persistent effort in the face of temporary failure. He scoffs at the unsuccessful result, unable to read its lessons and to see in it the index finger pointing the way to success.

The financial failure of cottage building in England has been often rendered more complete by the laws relating to the subject contained in the model byelaws of the Local Government Board, which I have mentioned before, and which, in many districts, have prevented the use of otherwise suitable materials. The recent Town Planning Act, has, however, modified this adverse condition, though it still remains to be seen whether public prejudice will not prove a still greater obstacle than the old byelaws to the adoption of unusual materials. I have met several persons from various parts of "greater Britain across the seas," who have expressed their astonishment at this prejudice, especially when it has related to its wooden building, which they have, perhaps, used almost universally. We have, however, to remember that, while such a building may be so contrived as to maintain an equitable temperature inside, in both hot and cold weather, we have in England the additional factor of damp to deal with. Still unreasoning prejudice has done more probably to prevent a proper solution of the housing problem than any other difficulty the case presents.

The cheap cottage having so largely failed, we naturally look for a substitute. This has been found in Germany, and in the Scottish towns in the large block of workmen's flats. They allow of a very much greater composite architectural effect than a collection of cottages would do. Nearly all the housing reformers in England, however, have a strong prejudice against workmen's flats, and, in support of their views, point out that in Germany itself, the home of this system, there is a strongly marked tendency to cease building in large blocks, and take up the English method of building separate cottages. A model of such a village was planned by a German Town Planning expert and exhibited at the Congress of Town Planners recently held in London. The opponents of block buildings also point out that, in such a block, one dirty, noisy or drunken tenant can make himself felt and heard throughout the whole building, whereas, in the self-contained cottage, while he still remains a disagreeable neighbor, his power of annoying others is greatly curtailed.

On the other hand, no one would deny that the block building possesses advantages of its own. Its economical use of the land available leaves more land free for the provision of playgrounds and open spaces, and, what is still more important, it facilitates communal services which lighten the financial and practical burdens of housekeeping, such as heating by hot water, the delivery of boiling water ad lib. by a faucet in every flat, well equipped laundries for use by the tenants in rotation, common kitchens and the like. It has also been pointed out that the block system of housing has never had a fair trial in Britain. It has always been taken up as a last resource by municipalities desirous of cleaning out a slum, except in the larger Scotch towns where bad ideals of planning resulting in the notorious Scotch "bed-place" in its worst form and other mistakes have prevented its success. It would be very interesting to see what would be the result if one were erected in one of the smaller towns of England on lines which would meet the prejudices and provide for the habits of life of the average British workman, and with an exterior which would be aesthetically presentable. We should no doubt be told that the English masses have not that capacity for hidebound method which is so prominent a feature of the Teutonic character, but that he is more individualistic and truly democratic, and that this would prevent the success of the scheme. Nevertheless, I should very much like to see it tried under proper conditions, and I should be much surprised if, when the first strong prejudices were overcome, it would not meet with a considerable amount of appreciation.

One criticism of the results of housing experiments which one hears repeated very often is, that the cottage when completed is very often occupied, not by the laborer, for whose benefit the experiment was tried, but by the townbred clerk or shop assistant. It is also said that the housing exhibitions held up and down the country in the last few years, have done far more towards providing the fairly well to do town dweller with a week-end bungalow in which he can spend his Sundays amid rural surroundings than towards solving the rural housing questions. I would reply that I cannot see where harm can result if, in endeavoring to solve one problem, we incidentally supply material for the solution of another, and that, in the case of the cottage inhabited by the clerk and the poorly paid shop assistant, we are doing a good work. Not only is he worse off than the workman who, while receiving the same or slightly more salary, has no appearances to keep up, but the very nature of his employment gives him a greater appreciation of, and therefore renders more necessary to him those refinements of civilization which are the result of increased capacity to appreciate the value of art and letters.

Where real harm has been done is by endeavoring to raise the ideals and methods of life of the average workman by so planning his cottage as to force him into methods of living foreign to his ideas of comfort. We can no more improve his tastes and habits by such means than we can make people good by Act of Parliament, and the effort to do so must necessarily end in his refusing to live in a cottage planned like a shooting box, and totally unsuited to his needs. In such a case we cannot be surprised if the cottage is taken possession of by the "week-ender."

ENGINEERING EDUCATION AT THE UNIVERSITY OF WISCONSIN.*

By Professor A. G. Christie, '01.

The University of Wisconsin is one of the largest of the American State Universities. It is maintained by taxes levied on the citizens of the state, and hence each feels that he has a real and vital interest in the work of this institution. The university has thus come to be regarded in much the same light as the elementary schools, in that it is intended to make higher education accessible to every young person in the state. The aim of the university must, therefore, be not only to maintain a high grade of scholarship, but also to provide education to which each is entitled according to his abilities. In other words, the university, by its dissemination of culture and learning, must tend to make better and more useful citizens of those who come under its influence. That these results are being achieved can be demonstrated by the leading position Wisconsin has occupied for a number of years with regard to progressive legislation and forms of government.

The same ideals prevail in connection with engineering education as in all other courses. There are two distinct departments engaged in this work. One department, the College of Engineering, provides a four years' training for students, covering the usual class room, drafting, laboratory and field courses, which work is all given at Madison. The other department, known as the "Extension Division," is doing splendid work in trying to reach, by local classes and by correspondence, those who for various reasons are prevented from attending the university itself.

The College of Engineering offers courses in civil, mechanical, electrical, chemical and mining engineering. These courses are all very broad, for it is necessary not only to make the student a good engineer, but at the same time to make him a useful member of the community. He is allowed a considerable number of elective studies throughout his course and is encouraged to elect those subjects which will help to widen his point of view of business, public and social problems.

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* Address to the Engineering Alumni Association, Engineers' Club, Toronto, Nov. 30, 1911.

The technical courses themselves are much more general than is usual in many colleges. The first two years are devoted to the study of languages—with much emphasis on good English—mathematics, mechanics, physics and chemistry. The third year is the first one in which definite engineering subjects are taken up. In the fourth year advanced engineering is taught, and at the same time a greater number of electives are allowed.

Formerly a student in civil engineering was taught nothing of steam engines or of electricity. At Wisconsin he has to take both class and laboratory courses in these. The mechanical engineering students take class and laboratory courses in direct and alternating currents, in hydraulics and hydraulic machinery, in surveying and in materials. Similarly, the electrical man takes full courses in steam and gas engineering and other courses similar to those specified for mechanicals. Mining and chemical engineers take courses that are similarly mixed.

It would seem at first glance that too general an education was provided instead of specializing in one particular line. Experience has shown, however, that an engineer nowadays must have this general knowledge, as his work is becoming more complex every day. Besides this, a student is seldom able to foresee the line of work that he will take up after graduation, and very often does start in some line quite different from his specialty when in university. His general knowledge of the other fields of engineering is then of inestimable value to him in his chosen work. A few such cases might be cited in this connection. One recent civil engineering graduate is now in the steam and electrical department of a public service corporation. Another is in the gas business. A mechanical is acting as civil engineer on one of the new Canadian railroads. An electrical is engaged in the manufacture of gasoline farm engines.

In the final years much emphasis is laid on commercial engineering subjects, such as contracts and specifications, economics, commercial, mechanical engineering, electrical applications, works management, chemical manufacture, plant design, etc., so that students get ideas of the economic factors which are of first importance in engineering practice.

The method of teaching is such that very few pure lecture courses are given. Usually a text is selected and the classes broken up into groups of about twenty men. Then work is assigned in the text to be prepared outside the class room and each meeting then becomes a recitation of this assigned work, with additional information from the instructor. Frequent examinations, known as "quizzes," are given to determine the progress each student is making in his work, and in many courses these take the place of, or rank equal to, the final term examination. This system requires steady and even work on the student's part, instead of the killing cram for one final examination, as in the old system. It also enables the class advisers to get rid of students who will not work or are totally unfitted for the course early in the year, and thus save expense to their parents or guardians and time to the student.

All laboratory courses and field courses are laid out so as to form merely the application of classroom principles. In fact, all courses are very closely co-related. It has been found advisable in most of the laboratories to provide printed notes and instructions for the students. While these may not be as helpful in all cases as personal instruction, on the other hand it does not leave the student at the mercy of the instructor, who may not at all times impart his information with equal efficiency. Uniform methods of conducting laboratories have been most gratifying to all concerned.

It will be noticed that in all work so far discussed the student's work has been very closely supervised. It has been objected that this tends to destroy the initiative of the student. On the other hand, it may be pointed out that the work of each graduate, after he leaves college, must be very closely supervised by his employers if mistakes are to be avoided.

To develop the initiative of the student each is required to prepare an original thesis for graduation. Very few of these are library subjects, and, except in civil engineering, cover principally experimental and research investigations. A subject is assigned to the student, or selected by him, and a member of the staff is designated as director of that work. This director holds conferences with the students, receives reports of progress, and generally guides the student from wandering from his subject, but, at the same time, the real work and thinking is done by the student himself.

The faculty have a busy time of it. Certain men are appointed class advisers for from thirty to forty students, and assist these men in the planning of their courses, help them in case of trouble, and are often even asked for advice on personal affairs. This ensures an intimate contact of faculty and students. Course committees and department committees meet weekly to discuss means and methods of teaching. The whole engineering faculty is called together monthly for an informal meeting to discuss such questions as "The Relation of the University and the Manufacturing Industries of the State," "The Utility of Research," etc.

No definite method has yet been devised whereby moral training can be provided for the students. Yet it has frequently been noted that the presence of the large body of female students at the university exerts a very beneficial influence over the men.

Both men and women have student self-government organizations, in which cases of discipline, etc., are handled without interference from the faculty.

Social life is very active in Madison. There are innumerable clubs, fraternities, sororities, etc., where the students of all courses mix indiscriminately. In fact, society affairs often become a burden on the students.

It is the policy of the university to encourage the members of the engineering staff to take up a certain amount of outside work, so as to be in close touch with actual engineering. Most of the men do so, several being connected with the State Railroad and Public Service Commissions. This outside work prevents the men from rusting in college routine and keeps them in touch with the latest developments in their special lines.

The Extension Division of the University of Wisconsin is doing probably the best work of any department. It reaches the tradesmen and those who are not able to attend the university. This work is carried on largely by correspondence, but a large corps of instructors are employed who visit local centers and meet the men taking the courses and help them over difficulties which are often hard to explain by correspondence.

Shop men and men engaged in industrial work often find the need of training in their vocation. This need was recognized by the organizers of the now famous correspondence schools. But these schools were run for commercial purposes, and men taking such courses often became discouraged at the slow progress made. The result was that courses were seldom completed, though fees were paid. The university conceived the idea that this matter of education was rightly part of the state's duty to its citizens, and organized the Extension Division to carry out this work. Vocational courses are offered, in which the necessary mathematics and fundamentals of the trade are taught, finishing up with applications of these principles to the trade itself. Classes of mechanics and apprentices have been organized at all large shops through the hearty co-operation of the employers, and one of the traveling instructors meets these classes at regular intervals. Headquarters have also been established in several of the larger cities, where regular night classes are held and instruction given in drafting, etc. Men with necessary high school training, but who cannot attend the university, are enabled to take the regular engineering work by correspondence, while most of the laboratory work can be taken at the summer sessions of the College of Engineering, at Madison. Those who are in business and have the means to take university work, but do not have the necessary high school preparation, can take up this preparatory work also by correspondence. Many men have been enabled to attend university by this method who would otherwise have been debarred.

This work has now been in progress three years, with very encouraging results. Time does not permit all the details to be discussed.

Wisconsin has been called "The Utilitarian University." This economic spirit, together with the democratic progressive ideas prevalent throughout the whole state, has reflected in the work of engineering education carried on at the university. The engineering departments strive not only to produce good technical and commercial engineers, but also to make all men who come within its influence better citizens of the state in which they live.

CLASS 1T4 DINNER

The Second Year "School" dinner, held at the St. Charles on Tuesday evening, Dec. 19th, was a success from every standpoint, and bespoke a great deal of work and sacrifice of time and study on the part of President Mechin and his executive. The speaking was excellent and extremely complimentary throughout to the year 1T4.

After the customary toast to the King, responded to with vigor by every man present, a toast to "The School," was proposed by Mr. "Pete" Campbell, in a manner quite characteristic of the quarter back of the Canadian championship team. In response, the Dean was delightfully reminiscent, and favored his hearers with a most interesting address, abounding with humor, upon his early difficulties, first in obtaining his own engineering education, handicapped by a lack of academic facilities, and second, in organizing and settling upon its great foundation the "School of Practical Science." The applause which followed the conclusion of his remarks exemplified the esteem in which Dean Galbraith is held by those who consider it an honor to be enrolled members of class 1914.

A toast to the engineering profession was next proposed by Mr. P. L. Fansher. Prof. Haultain, in reply, cited the work of the engineering world as the most important in the knowledge of man. Notwithstanding this, the engineer continues to be poorly paid for his services, and his contentment with conditions has only of late years become cognizant of the agitations of able-minded engineers in asserting the rights of the professions to adequate remuneration for services.

Prof. Haultain commented favorably upon the work of the Engineering Society as being exceedingly helpful, and urged his hearers to make the best of the opportunity afforded by its meetings.

The toast to the "Year one-T-four" was proposed by Mr. C. V. Perry, past-president. Mr. Perry took this opportunity to congratulate the year on its selection of a president in Mr. Mechin, to whom all praise for such an excellent night's entertainemtn was due.

Thos. R. Loudon, the popular honorary president of the year, in replying to this toast, said he was very glad to be connected, as he was, with the class, but regretted that he could not be of any material help to them in their work this term. He promised his best services, however, on election night for the tug-of-war contest. Mr. Loudon was very humorous throughout, recalling old memories of a turkey fight last Christmas. He agreed that the modern engineer had a great advantage in the new branches of learning, over his old, and often too theoretical fellow-worker. He urged the men to maintain their loyalty to each other and to the University, as the life of the University depended upon it.

The toast to "Athletics" was proposed by "Jeff" Taylor. "Jeff" thought that athletics should be, perhaps, next to studies, most important to the student. More physical exercise was urged, to instil athletic enthusiasm into those who did go in for athletics of any kind.

In replying, Prof. Wright spoke well of the achievements of University men in the field of athletics.

His address is given in part, as follows:—

I have to thank you for the story the Dean has just told us of his application for the position of Professor of Engineering. I have had the pleasure of listening to him on many public occasions. It has also been my privilege to listen to him at many semi-private and private gatherings; but, until this evening I have never heard the complete story of his application for this position.

A good deal has been said already this evening about the value of the Engineering Society and the work done by the various student executives, and in this connection I would like to draw your attention to the fact that Professor Haultain, who is with us this evening, was the first student president of the Engineering Society.

When your president, Mr. Mechin, asked me to respond to the toast of athletics, I felt quite honored: first because of the importance of athletics in college life; and for that matter, in the life of Canada to-day; and secondly, because of the prominent part taken in athletics by this Second Year of the S. P. S.

Now, because I may be misunderstood, let me say at the outset that you are present at the University primarily for a mental training and development, that academics comes first always. I know that you have given the very best of evidence that you appreciate this fact, for at your final examination last year over 80% of the Year passed; to be exact, 83% made a success of their academic study: a record of which we know you are, and are entitled to be proud. In this connection I am satisfied that when the work of the present session, 1911-1912, is reckoned, you will have established another record from the standpoint of the class list. At the present pace, in two and a half years the most of you, I would like to say all of you, will be graduates of the University of Toronto, an institution that has an enviable world-wide reputation in engineering, a reputation that has been made by the graduates and one that will in a few years depend upon you and your record; and we know that you will not be satisfied until you have placed the standard even higher than it floats at present.

When the average citizen is handed a report of an engineer and is requested to advance money on the strength of it, what are the usual questions asked? Does he not rather examine the engineer than his report? Can the questions not be grouped under two heads, viz.:—(1) Honor; and (2) Ability? Would the questions not run something like this? Can I trust this man's word. Does he always speak the truth, the whole truth, with conviction? I am sure that if you could interrogate the distinguished engineers who stand at the head of their profession to-day, you would find that they invariably value their word, their honor, above averything else.

The second lot of questions would be for the purpose of finding out whether the engineer under consideration has the mental equipment necessary to solve the problems under discussion, the power to organize and administer—the executive ability, if you will. Is he strong enough to act as an efficient leader and at the same time co-operate in the broadest sense with others and with other departments for the welfare of the undertaking? And lastly, has he had the necessary experience in life?

Now, I believe that college athletics, when properly conducted, help very materially to develop such a man. A vigorous and healthy mind requires a healthy body. Exercise is necessary. Every student should take a proper amount of exercise regularly. The greatest value of athletics in our University lies in the fact that so many hundreds of men participate. We cannot deny that among this multitude we have many individuals who have won distinction in athletics for their university, for their faculty, for their year, and for themselves. Who is to-day the greatest Canadian quarter-back? Pete Campbell. (Pete Campbell was immediately elevated by his fellow students, who sang, "For he's a Jolly Good Fellow.")

Gentlemen, I have said before that I believe college athletics would help to develop a man's power of co-operation, this executive ability, and enable him to place a better value on his honor. Who, for example, could imagine Pete Campbell, even in the stress and excitement of play, doing a mean, dishonorable, dirty act? This silence, I interpret as meaning that you, his fellow students, believe as I do, that it would be impossible. Or, again, who could imagine Pete accepting as a reward (?) a house and lot, or anything else representing a large financial recognition? . . . No, the laurel branch, the honor, the testimony of his fellow students as given to-night, the more humble testimony of members of the teaching staff, of our Dean and our president, represent the real reward. Now, this condition of things is not peculiar to amateur athletics; but is a condition of real life. We have already heard this evening that the engineer, as a rule, is underpaid. I want to draw your attention to the fact that his real reward consists in having done something well, and the most severe punishment ever meted out to the engineer is the personal conviction of shortcoming, of failure.

A few years ago one of the most respected and ablest of our engineers, a man well-known throughout the world as a leader among engineers, attempted to build a gigantic cantilever to carry a roadway at a dizzy height above the mighty St. Lawrence. This attempt, as you know resulted in a scrap pile on the banks of the river. Now, while the monetary loss was very considerable, while there was a very regrettable loss of life, the saddest feature of all, I believe, was the punishment meted out by this failure to the grey-haired engineer as an anti-climax to his otherwise remarkably successful career. It is but necessary here to remind you that he died, broken-hearted over this calamity.

Now, let me refer you to the other side,—the reward of success. You heard earlier this evening of a graduate of the University of Toronto in Arts, an engineer of considerable experience, who left a position worth $2,700 a year to make application for a position at $1,800. He told us that he thought of this work as other engineering positions, as an opportunity to gain a wider experience. He might equally well have said that he felt there was a gap in the teaching at the University of Toronto, a gap in the educational system of the Province of Ontario, that he thought should no longer exist. Starting as Professor of Civil Engineering, he has proved to the satisfaction of the educational authorities of Ontario, of the University of Toronto, the engineering profession and of the general public, his ability to bridge that gap. After a few years of service he was appointed Principal of the S. P. S., and is now the honored and respected Dean of a prominent faculty in our University. I ask you, what has been the reward of this engineer? It certainly has not been, and is not to-day, the salary, but lies in the consciousness that he has carried out successfully a noble work, and in the glad hand and warm heart extended to him by graduates of this institution scattered over the world.

Now, I say the real rewards in life are the laurel branch, the honor and the testimony; and amateur athletics offers a good training to any young man.

There are other examples of prominent athletics in this class of 1T4. Your list contains the names of the fastest of Varsity's wings —Jeff Taylor and Bobby Sinclair.

Connected with every team there are men of whom we hear very little, but, who have very difficult posts to fill. They are the man who must train, who must sit on the side benches and see their fellows taking part in plays which they themselves realize they could carry out equally well; men who must be ready at a moment's notice to take the place of an injured player and carry on the organized team work without a hitch. I refer, of course, to the spare men; and I say all honor to two of your men, Gardner and Macdonald, who filled these important positions. It would not be fair were I not to mention the enhusiastic way in which the executive work of athletics is carried on in our midst, and in this connection, although they are not members of this year, should be mentioned the names of the president (Duff Wood), the secretary (Galbraith) and the manager (Mulqueen), of the Rugby Club.

While we still have on our minds Rugby, I should like to say that I believe there is nothing around the University that helps to create college spirit and loyalty more than athletics. Just think for one moment of the amount of work done in order to produce organized rooting at our great games, and we are proud of those who act as leaders in this work, among whom you as a Year are ably represented in Mr. (Dutch) Macpherson.

I am sure you all read with a great deal of interest your copies of "Varsity" this morning. I would refer more particularly to the first column of the first page headed, "School Wins Championship in Water Sports." Let me call your attention to the fact that of the 63 total available points, School won 32, and it is a pleasure to realize that the School won from a polo team selected from the entire University by the score of 6 to 4. In this department of athletics, you, gentlemen, were well represented; one of the prettiest races of the day being that between Mr. Foote of the Third Year and a representative of your Year, I mean Mr. Tillson. (Stand up, Tillson). Mr. Tillson is rather bashful; he is more at home in the water. In connection with these same sports I should mention Mr. Binns also of this year, and there could not have been such a tournament in water sports it if were not for your representative, Mr. Rutherford.

In soccer, that grand old game of Association Football, you were ably represented by Messrs. Gray and Macdonald. In wrestling I have but to mention the names of the Ross brothers. They need no introduction from me. In boxing you have Messrs. Taylor and Rex Davidson; in hockey, Messrs. Cotton and Strome; in shooting, Mr. Mills. I am nearly forgetting that early in the season we had a track meet. Here the School did not shine particularly, but there was a large number of School men "who also ran." However, the Second Year men will feel proud of the record of two of its number: Messrs. Simpson and Perry.

I repeat, gentlemen, that I am very glad of the opportunity given me to-night, because of the prominent part you have taken in college athletics and of the part athletics play in life, not only of the University of Toronto, but of Canada in general.

During one week last fall, I had an analysis made of the material printed in three of our morning papers; and, as they represent the attitude of our country, this analysis is of importance to us. From 45 to 50 per cent. of the papers is devoted to advertising; while news of the day occupies from 25 to 35 per cent.; the editorials, ladies' column, etc., from 1 to 8 per cent.; the markets from 5 to 16 per cent.; and sport from 5 to 11 per cent. On the mornings after special sporting events, the morning papers devote from 8 to 13 per cent. of their space to athletics, while the average for a whole week of all three morning papers gives over 8 per cent. An average paper would then be made up as follows:—50% advertising; 28% news; 8% markets; about 5% editorials, etc.; and 8½% athletics.

In conclusion, I would like to remind you of the fact that the final game of Rugby for the championship of all Canada was played without a single player having to be sent to the side lines for "dirty" work. This is a record for clean playing of which the Argonauts and the University of Toronto may justly feel proud.

Before closing, I must in all fairness to our sister universities in Canada, say that they have been setting an equally high standard of purity in sport with Toronto. In some instances our sister institutions are to be doubly complimented, because they have accomplished this high ideal under more trying conditions than those that exist in the University of Toronto. That college athletics is leading the van in the matter of clean athletics, has been testified to and commented upon widely, not only by the press of Toronto, but by the press of Canada as a whole.

The toast to the Applied Science students was proposed by Mr. H. M. Black, and responded to by Mr. L. T. Rutledge. Mr. Black noted with regret that there was no toast to the ladies, but thought this was somewhat closely connected to it. It might even be said that the two sometimes go hand in hand.

Mr. Rutledge, in responding to the toast, said that last year he was pleased to be demonstrating to the year one-T-four, but this year he was even delighted to be still with them.

The Science students, explained Mr. Rutledge, were supposed to finance all damages wrought by the University students in general, owing to a name they had for being rough. However, at the Belleville Y.M.C.A. conference this year, the School was the best represented faculty of the University. Even the landladies throughout the city have been known to refuse admission to their homes to Art and Medical students, but were always glad to get the Science men.

The Science course was the broadest course taught in the University, thanks to untiring efforts of the Dean. A specialist in Engineering receives also, as much remuneration as specialists do in Medicine or Law. In Africa, where the engineer has wrought so much in bridge and railroad work, the natives looked upon the engineer with great reverence, and suggested that the engineer might make a very good missionary.

The Science man was brought into contact with all classes of people, and was constantly in very trying difficulties. An example of this was the great Porcupine fire last summer, where one Science man lost his life, while Mr. Fred Andrews and J. S. Taylor, but of Second Year, had a hard fight for their lives, the former struggling until overcome by the flames to save the life of his companion. Mr. Rutledge said he once asked a very well-informed business man what distinguished a Science student from all others. His answer was, "Oh, they're a little rough but, of course, they know more." Mr. Rutledge closed with a poem written by Mr. Brock, demonstrator in II Year drafting room, a "fitting epitaph."

THE SCHOOL OF SCIENCE MAN

BY W. BROCK, '10

Who is this ever present youth?
We notice everywhere
His warlike features, sturdy form.
And head of bristling hair.
His clothes are built on ample lines,
His boots are brilliant tan;
At all the high class shops, he's known
As the "School of Science Man."

He hits the city every Fall,
To blow his summer stake,
And shakes a fare of pork and beans
To dine on cream and cake.
His survey togs are laid aside,
He shaves his face of tan,
And has his fling at everything,—
This "School of Science Man."

The first night in, true to his kind,
He views the giddy show.
He stands in line at six p.m.
To be first in the row.
It matters not what be the plot
Or how the story ran;
He breathes the air of heavenly "gods"
This "School of Science Man."

Next day he strolls 'round to the "School,"
And with a lordly grace,
Counts out his breakage fee and, p'raps.
Looks up his drafting place.
He sniffs the stuffy lecture rooms—
They reek beneath his ban—
And then he seeks a purer air—
This "School of Science Man."

Up to the stale old Gym he goes,
And rakes his locker through
Until he finds his moleskin suit
Of musty White and Blue.
When on the campus he appears,
See every football fan
Leap to rejoice, with lusty voice,
And hail the Science Man.

For he's the mainstay of the Firsts,
The Thirds and Seconds too:
In fighting for the Mulock cup
He's shown what he can do.
Upon the field and running track,
He's always in the van—
Cool, strong and square, sure, fast and fair—
Your "School of Science Man."

And thus it is in every sphere
Of College sport and life—
The Science chap—always on tap—
To join in peace or strife.
In swimming, boxing, wrestling too,
(If the records you will scan),
You'll always find not far behind,
The "School of Science Man."

And then there are the gentler arts,
Ordained by "fussing" Fates,
Such things as Glee Clubs, Dinners, Balls.
Receptions and Debates.
When the "Toike Oike" is asked to sing,
Or speak—if speak he can—
Or fuss, or talk, or dance, or walk—
He always plays the man.

And when the School Man graduates,
To roam the wide world o'er,
His fight and vim go out with him
And push him to the fore.
It matters not where he may be—
Yukon to Yucatan—
With wealth and fame he links his name,
This "School of Science Man."

And when the final trump rings out,
And Gabriel wakes the dead
From out their sleep so long and deep,
With Adam at their head
You'll surely see, with certainty,
As the Heavenly ranks you scan,
Some "Arts" and "Meds"—They're all good "heads"—
And many a Science Man.

FUTURE MEETINGS

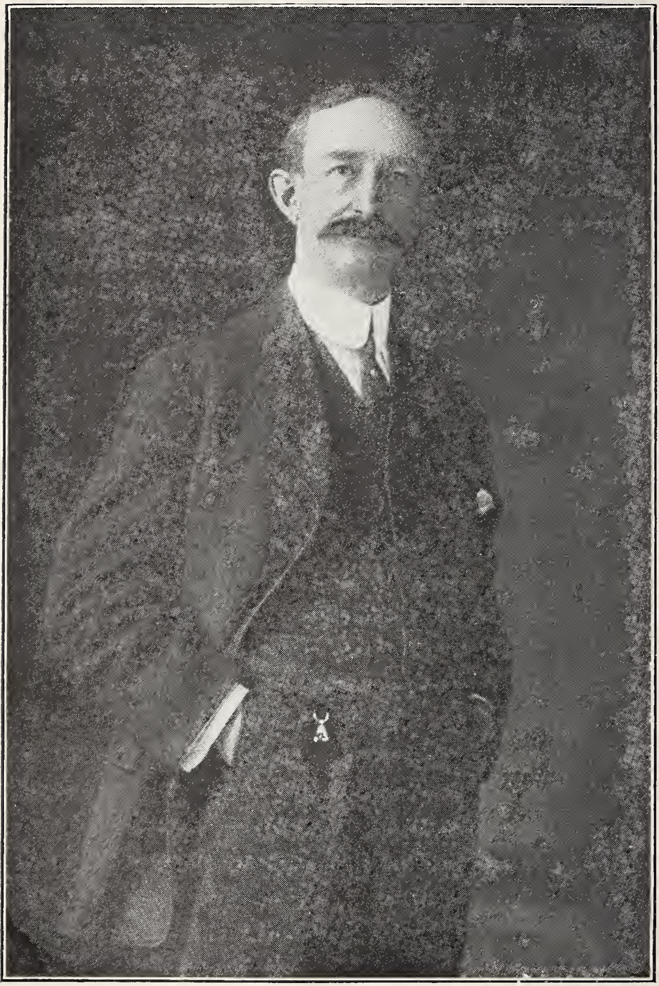
On Wednesday, January 31st, Mr. Frank B. Gilbreth, of New York, will address the Society upon the subject of "Scientific Management." Mr. Gilbreth's investigations are world-famous, and the Society extends to every graduate who can possibly be present, a hearty invitation. The prospect of listening to this authority on such an important subject is creating immense interest among those who already know of his coming, and in order to enable the Society to gauge the attendance and to provide the most suitable accommodation, graduates in the city and vicinity will confer a favor by replying by post card as to the probability of their being present at 4.30 p.m. on Wednesday afternoon, Jan. 31st.

On February 14th, W. H. Boyd, '98, of the Dominion Geological Survey Department, Ottawa, will deliver an address on the work accomplished in his department, particularly in the topographical surveys branch. This will also be an afternoon meeting, and an attendance of graduates is requested.

APPLIED SCIENCE

A good deal of consideration is being given this journal by its publishers, the Engineering Society, relative to its publication monthly throughout the entire year. The many points under discussion appear to be almost unanimously in favor of the twelve-issues-per-year proposal, and in all probability the next issue will announce its adoption.

We would like to have as many graduates as possible air their views upon the question, and will appreciate every opinion they take the trouble to submit.



Applied Science

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PROFESSOR GEORGE A. GUESS

The new Professor of Metallurgy is a graduate of Queen's University, M.A., 1904. He took the honor chemistry and science course, and also took a course in the School of Mining. His early work was in British Columbia, in various subordinate positions. He left a position in the Trail smelter to go to Colorado, where he spent a year in the San Juan district. He was for two years or more with the Greene Cananea Company, in Mexico, getting a wide variety of metallurgical experience in various investigations in those extensive works. From here he went to the Tennessee Copper Company, as assistant, and was soon after, raised to the position of metallurgical superintendent. After four years in Tennessee he went to the Cerro de Pasco Mining Co., in Peru, as metallurgical superintendent and assistant general superintendent. The smelter was situated at an altitude of 14,000 feet. Mrs. Guess could not live at this altitude and Mr. Guess returned to the States towards the end of last year, when the authorities of the University of Toronto, who for six months had been seeking both in America and in Europe for a man for the position of Professor of Metallurgy, were fortunate in securing his services. He has always been a deep student of his subject and an occasional writer for the technical press. His work has been marked by originality and conspicuous success on a very large scale.

The capacity of the Tennessee Copper Co.'s smelter was 40,000 tons of ore per month. It had for years been a school for metallurgists seeking information on pyritic smelting. When Mr. Guess took charge, he modified considerably the practice, making material reduction in working costs. The monthly output at the Cerro de Pasco was 4,000,000 lbs. of copper, besides silver. He has visited and studied most of the large metallurgical plants in America. He will be a very valued acquisition to the Engineering Faculty and to the mineral industry of Ontario. In welcoming him to the University, "Applied Science" would endorse the warm and enthusiastic reception tendered at the Engineering Society dinner, and wish him the measure of success in academic work that he has achieved throughout the length and breadth of the profession he follows.

RECENT DEVELOPMENTS IN ELECTRIC IRON SMELTING

By Thomas D. Robertson, M. Met.

Before considering in detail the newest process for the manufacture of pig iron from its ores on a large scale, it may be well to consider some of the features of the older and more generally employed process, namely, blast furnace smelting. As is well known the iron ore to be smelted is mixed with fuel, usually in the form of coke, and a certain amount of limestone, the latter being for the purpose of fluxing the earthy material of the ore and producing a fluid slag, which can be removed from time to time. By the action of the carbon in the coke upon the oxide of iron in the iron ore, metallic iron is produced, and owing to the heat supplied by the combustion of the fuel with the blast of hot air blown into the furnace the reduced iron melts and collects in the furnace bottom, being tapped off at suitable intervals.

The action of the coke is two-fold: About one-third of the carbon supplied is used up in uniting with the oxygen of the iron ore and thus accomplishing its reduction, whilst the other two-thirds is burnt by the oxygen of the air blast to produce sufficient heat to enable the various reactions to take place. In common practice rather more than one ton of fuel is used for every ton of pig iron produced, and not only must this fuel be of a high grade chemically, but it must possess mechanical strength and sufficient porosity.

The electric furnace has been used for a number of years now in the reduction of certain metals and in chemical processes, but it is only comparatively recently that it has become possible for electricity to be economically used in the production of the commonest of all metals, namely, pig iron. The electric furnace, however, was successfully used on quite a large scale for the production of steel, before it was applied with any measure of success to the reduction of iron ores.

The large amount of fuel, and incidentally fuel of very special quality, which is necessary to smelt iron ores in the blast furnace, has had an important effect upon the iron industries of those countries which were unfavorably situated with regard to their fuel supplies. Canada is one of those countries, and as it is only in the extreme East and West that coal has been found which will give a coke suitable for blast furnace smelting, furnaces operating in central Canada have perforce to use coke imported from the United States. Now, it was calculated that the electric furnace would dispense with two-thirds of the fuel required in the blast furnace, substituting electrically produced heat, for the heat chemically produced by the burning of this portion of the fuel, the other one-third of the fuel necessary for the reduction of the iron ore being employed in the electric furnace in the same manner as in the blast furnace. It seemed, therefore, that if electrically produced heat could be successfully substituted for the heat obtained from the burning of expensive fuel a saving in cost would be effected, and with this object in view the Dominion Government of Canada, in 1904, appointed a commission to visit the various electric furnaces in operation in the iron and steel plants of Europe. The result of this work was embodied in an exhaustive report, which showed in general, that whilst furnaces were working successfully on a commercial scale in the manufacture of certain grades of steel, electric smelting of iron ores was as yet in its infancy. As it was this latter branch of the subject which was of most interest to Canada, the Dominion Government decided to build an electric furnace, under the supervision of the Department of Mines, and carry out a series of trials with the object of deciding whether the electric furnace was suited to the treatment of the various Canadian ores, and whether it seemed probable that the process would be commercially successful when carried out on a larger scale. A furnace was built in 1905 at Sault Ste. Marie, and operated successfully, its scope being limited by its size and by certain features of its design. The publication of the results obtained, however, aroused more interest in Europe, particularly in Sweden, than they did in Canada. Sweden, having no domestic coal suitable for smelting, has always used charcoal for blast furnaces. Owing to the rapid growth of the wood pulp industry, and consequently increased demand for wood, the price of charcoal has steadily risen, so, in view of the fact that the fuel problem was becoming acute, three Swedish engineers, Assar Gronwall, Axel Lindblad, and Otto Stalhane, formed a company, called the Aktiebolaget Elektrometall, in order to design and build an electric furnace which would be capable of producing pig iron continuously in large quantities. Assistance was given to them by several of the largest iron works in Sweden, and their experimentation is an interesting example of how, after several failures, a successful design was evolved which, although small modifications may be made from time to time, is now generally admitted to be one according to which all the future electric iron smelting furnaces will be built.

As many of the difficulties which had been experienced in the Canadian trials were due to the electrodes employed in the furnace, attempts were made by the Swedish engineers to design a furnace which would do away with the necessity of using carbon electrodes, and their first furnace embodied the principle of a shaft similar to that of an ordinary blast furnace, having two channels in the hearth at its base. The furnace was started as an ordinary blast furnace, arrangements being provided to introduce an air blast through twyers, and when sufficient molten iron had collected to fill the two channels, which in turn were connected to the terminals of a transformer, the current flowed between these two channels, passing through the charge, which was thereby heated sufficiently to cause fusion, and the continuous production of pig iron. The idea was that the electric heating would take the place of the heat generated by the burning of fuel in the blast furnace, and that the ore could be smelted with just sufficient fuel to reduce it to the metallic state. The lining of this first furnace was made of silica brick, and it was found that after working for short periods the heat generated on the bottom was sufficient to cause the fluxing of the brick, and after a time a short circuit occurred between the two channels.

This furnace was therefore reconstructed with a bottom of magnesite and a much more solid construction, and instead of the current being introduced through two channels parallel to one another, it was brought in at opposite sides of the furnace. The hearth lasted better than before, but the same difficulties were, in general, experienced, and it became evident that the introduction of the current through the bottom of the hearth was not likely to lead to success.

The next plan adopted was to have two electrodes placed horizontally in the shaft of the furnace, with their surfaces just flush with the interior surface of the brick work, and to have a third electrode placed in the hearth. The electrical arrangements were such that the current could be caused to flow between the two electrodes embedded in the side of the shaft, or between these two electrodes and the electrode embedded in the bottom. Here again, although this furnace was an improvement upon either of the two types above described, yet the intense heat developed on the surface of the brick lining was such as to cause the very rapid wearing of this part, and consequently the furnace did not run very long before requiring to be relined.

It seemed, therefore, that if a successful furnace was to be designed that the electrodes should not be completely surrounded by the charge, neither should they produce their arcs close to either the lining of the furnace shaft or the bottom. A fourth furnace was constructed, therefore, a section of which is shown in Figure 1, having two parts, a shaft to contain the charge of ore and charcoal, and a melting chamber below, having an arched roof through which the electrodes projected. As in all furnaces heated by the electric arc, the point at which the heat is most intense is at the end of the electrode, but in this case this intensely heated region was kept in the centre of the smelting chamber, whilst the outside brick walls were saved most of the severe heating, which they had had to stand in the previous types of furnaces. Preliminary trials with this small furnace were successful and seemed to indicate that the correct principle had been discovered, so that, in 1908, a furnace was built upon this design improved and modified at Domnarfvet. This furnace had a shaft 20 ft. high, and was rated at 750 h.p. Three electrodes of amorphous carbon were employed to introduce three phase, low tension alternating current into the melting chamber. Further, an improvement was introduced whereby the gas produced by the reduction of the iron ore could be taken from the top of the furnace shaft, and after passing through a dust catcher, could be blown by means of a fan into the melting chamber immediately underneath the arched roof, cooling this latter, and

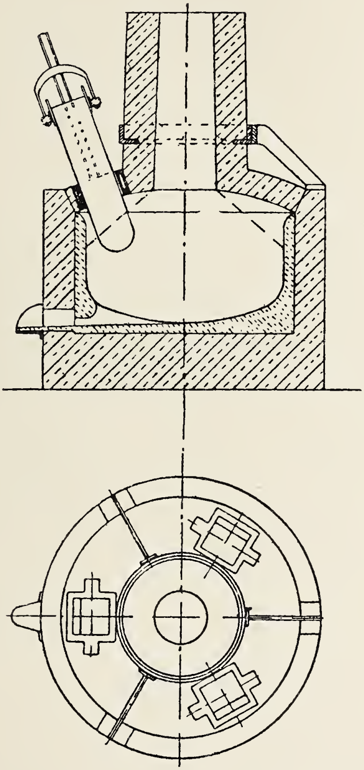


Fig. 1—Showing design followed in Domnarfvet Furnace

preserving it from being fluxed by the radiation from the intensely hot arcs. This gas, after passing underneath the roof, naturally became heated to a fairly high temperature, and as it all passed up the shaft it gave up this heat to, and assisted in the reduction of, the descending charge.

This furnace at Domnarfvet produced about 2 tons of pig iron per electrical h.p. year consumed in the furnace, and ran continuously from the beginning of May, 1909, to the 30th July, when it was closed down although in good running order, in order to make certain alterations. The consumption of electrodes was exceptionally low, considering the small size of furnace, and the fact that it was smelting iron ores, being only about 18 lbs. of electrode per ton of pig iron produced.

The results of the working of this furnace created great enthusiasm throughout the whole of Sweden, indicating as they did that some successful method of reducing the consumption of charcoal necessary to produce pig iron under the present conditions was about to be developed on a large scale. Jernkontoret, an organisation of Swedish ironmasters, founded nearly 200 years ago, which, although having accumulated large funds, had never before embarked in a commercial undertaking, determined to put up sufficient money to build a furnace similar to the one at Domnarfvet, but on a much larger scale; in fact, one comparable in every way to the Swedish charcoal blast furnace. Their intention was to smelt the various iron ores in general use in Sweden in this electric furnace, and to test the resulting electric pig iron against the Swedish charcoal blast furnace pig iron produced from the same ores, in order to determine the relative quality of pig iron produced by the two methods as well as to determine the relative costs.

The site chosen for this large furnace was at Trollhattan, where the Swedish Government has recently installed a large hydro-electric power plant, from which a supply of power could easily be obtained. The current is three phase, 25 cycles, and is generated at 10,000 volts. It was thought advisable in this particular furnace to transform the three phase current by means of two transformers, with Scott's connections, to low tension two phase current, in order to have the furnace built with four large electrodes rather than with six smaller ones, which would have been needed to use three phase secondary current. The new furnace site was supplied with railroad connections, and a large storage house for the charcoal was built to contain a six months' supply. The furnace itself is in a large brick and stone building, according to the prevailing Swedish practice. The construction of the furnace is shown in Figure 2, two separate portions are to be distinguished, namely, the shaft and the crucible or hearth. The shaft is simply a shell of steel plate lined with fire brick. At the top it is riveted to an octagonal channel iron ring, which bears on two built up beams, these being in turn supported by the walls of the building. In this manner the roof of the hearth is not called upon to support the weight of the shaft containing the charge. At the top of the shaft is a Tholander charging bell, a type of bell peculiar to Sweden, which is specially designed to deliver the ore round the sides of the shaft and the charcoal in the centre.

The crucible or hearth rests on a concrete foundation, which also has a steel shell, next to which is a lining of fire brick with an inner lining of magnesite brick, whilst the bowl-shaped bottom is formed by ramming in a mixture of magnesite and tar. The arched roof is built of fire brick and has four openings to admit the electrodes, which project through the roof at an angle of 65 deg. to the horizontal, and are surrounded at the point where they pass through the roof by a copper water jacket with asbestos packing to prevent the leakage of gas. The electrical contact pieces are wedged between the upper end of the electrode and a holder of cast steel, which is supported in a frame that can be raised or lowered between two guides, one on either side of the electrode. Figure 2 also shows the gas circulating arrangement, the function of which was described in connection with the Domnarfvet furnace. The four twyers through which the cool gas is blown are situated between the electrodes. This

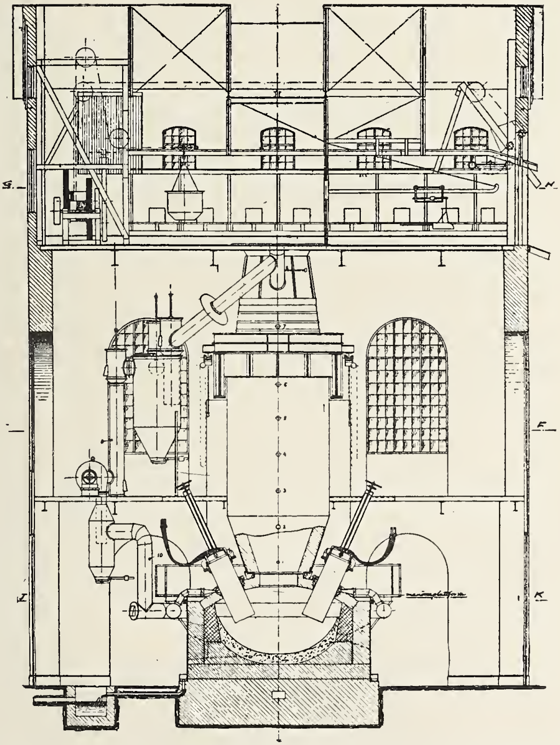


Fig. 2—Showing construction of the Trollhattan Furnace

Trollhattan furnace is rated at 2500 h.p., and current is supplied by two transformers, each of 1,100 K.V.A. capacity, oil insulated with water cooling. The tension of the two phase secondary current can, by altering the number of primary windings, be regulated in steps of 5 volts between 50 and 90 volts, and a change of tension can be made whilst the furnace is working by simply turning a hand-wheel, and arrangements are also such that the two phases can work at different tensions.

The low tension copper busbars from the transformers to the furnace are 24 in number, each 8 x 200 m.m. cross section. From these bars to the electrode holders the current is carried by flexible bare copper cables. The switchboard was fully equipped with numerous instruments in order that as much data as possible regarding the working of the furnace could be obtained. The chemical laboratory was fitted out with apparatus for the rapid analysis of the furnace gases of the various materials used and produced at the plant.

Charging was commenced, after the furnace had been thoroughly dried out, on the 15th November, 1910. In working the furnace the ore is taken from the stock pile, crushed and elevated to the furnace top, where small storage bins are provided, from which the various charges are accurately weighed out. Each charge of ore is mixed with a suitable proportion of limestone and charcoal sufficient for its reduction, and dropped into the furnace from time to time, tappings of molten iron being made about every 18 charges, corresponding to 4 tappings per 24 hours. By varying the amount of charcoal, grey or white pig iron can be produced at will, and numerous experiments were tried involving the use of different kinds of slag. This, however, was not good for the lining of the furnace hearth, and it must be admitted that it was something of an achievement for it to stand six months of such treatment without needing any serious repairs. The electrodes which were employed were built up of 4 separate pieces each 12 in. square by 6 ft. long, as at the time the installation was made carbon electrodes in one piece of the necessary dimensions could not be obtained. In order that the electrodes should not be overheated the current did not exceed 17,000 amperes, the voltage being regulated accordingly. The electrodes were only lowered into the furnace about once every two weeks in order to adjust their wear. Besides being abraided by the charge, the portion of the electrode in the free space underneath the roof of the hearth is subject to the action of the furnace gases, which contain about 20 p.c. of carbon dioxide, which unites slowly with the carbon of the electrode forming carbon monoxide gas, so that the stump ends of electrodes which have been removed from the furnace have exhibited curious shapes.

The furnace was shut down at the end of May, 1911, in order to make certain alterations suggested by the experience gained during its six months' campaign, two of these deserving mention.

1. Since the furnace was designed, the manufacture of large carbon electrodes, of high conductivity, has made great progress. It is now possible to obtain cylindrical electrodes of 600 m.m. diameter, fitted with screw joints. These have recently been installed at Trollhattan, and result in two considerable improvements, the first one being that the loss due to stump ends is done away with, as when an electrode becomes too short, a new one

can be screwed on above it. The second one is that the electrical contact can be made at the point where the electrode enters the roof, in this way saving about 40 kw., which, with the old arrangement, was lost, due to the resistance of the whole length of the electrode through which the current had to pass.

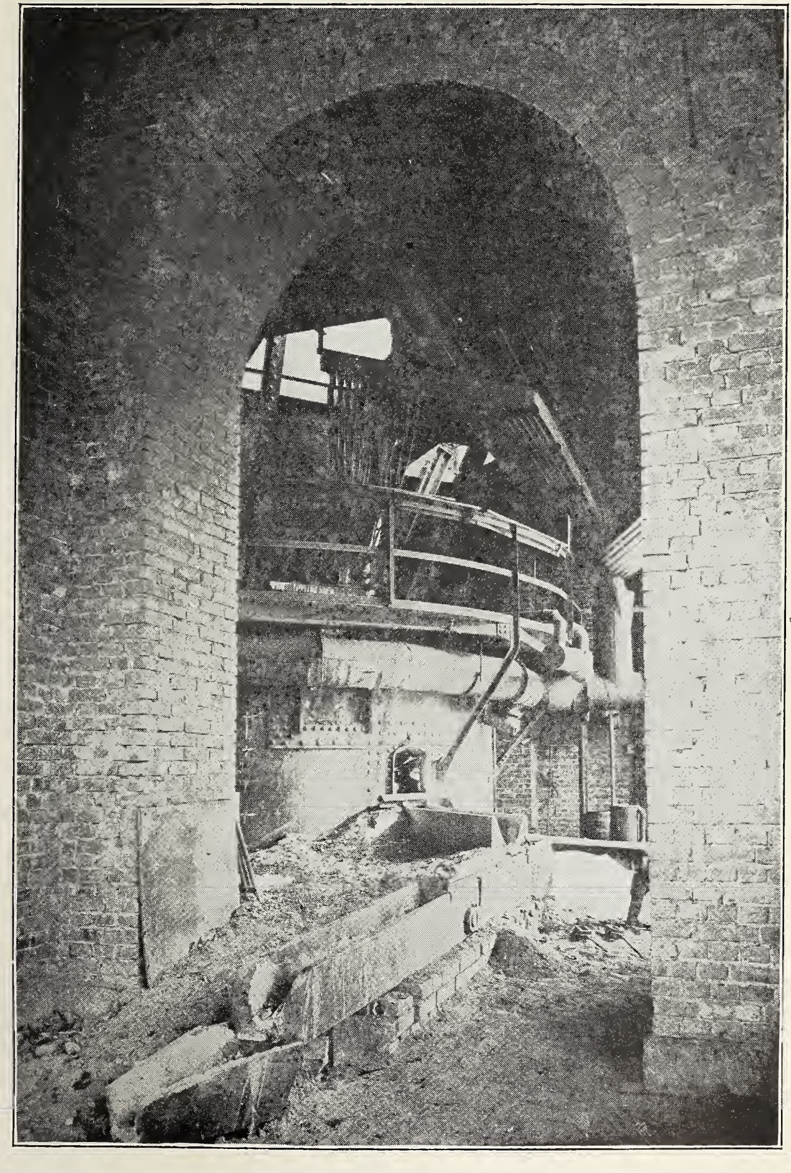


Fig. 3—General view of lower part of Trollhattan Furnace

2. The other important alteration is in the gas circulating arrangement. The old dust catcher was not very effective, as only very fine dust is expelled from the furnace. The result was that the dust collected in the centrifugal fan, and had it not been that this was kept fairly clear by a jet of water, would have choked up the blades in a few hours; as it was, the fan had to be stopped and cleaned every week. Now, a water scrubber takes the place of the dust catcher, and a fan on the ground floor blows the cleaned gas into the furnace, and the other fan shown being held in reserve.

A comparison between electric and blast furnace smelting is of interest. It has been found that rather more than 3 tons of pig iron are produced by the electric furnace for each E.H.P. year consumed, about one ton of charcoal (or coke) being necessary for the reduction of ore. To produce the same amount, namely, 3 tons of pig iron in the blast furnace, requires rather more than 3 tons of charcoal (or coke) so that the difference between the two processes, roughly speaking, consists in the substitution of one electrical h.p. year for 2 tons of charcoal (or coke). As power can be obtained in Norway and Sweden at a price per h.p. year very much less than the price of 2 tons of suitable fuel, apart from other advantages of the electrical process, a considerable saving is effected in cost. Further, by the utilization of water power in place of the burning of fuel the national resources of the countries are conserved.

The latest results obtained at Trollhattan are worthy of mention, being considerably better than those obtained at the commencement of the work. From September 3rd to September 30th, 1911, 538 metric tons of pig iron were produced, accompanied by 89 tons of slag, although the average load on the furnace was rather less than 2,000 h.p. The current used per ton of iron produced was 1,749 k.w. hours, corresponding to a production of pig iron per h.p. year of 3.68 tons, whilst the charcoal consumed was about 750 lbs. per ton of iron, and the electrode consumption was further reduced to 11 lbs. for each ton of iron produced. At the present time there are working and in course of erection in Sweden four furnaces, with a total capacity of 13,000 h.p., and in Norway four furnaces, with a capacity of 12,000 h.p., whilst in addition furnaces for about 36,000 h.p. are projected. These figures indicate that electric smelting has passed beyond the experimental stage, and in Scandinavia electric furnaces are now thoroughly established upon a commercial basis.

Some features of the possibilities of the electric furnaces are of considerable interest from a Canadian point of view. There are in Canada extensive deposits of low grade iron ores which require magnetic concentration to render them suitable for smelting. If large quantities of these concentrates are to be used in the blast furnace they require to be briquetted or nodulised, in itself an expensive process. The electric furnace at Trollhattan, although the design of shaft is not very suitable for smelting concentrates, has, during a considerable period, smelted charges consisting of over 65 p.c. of very finely divided magnetic concentrates without causing any trouble, and it is believed that by modifying the shape of the shaft, charges made up entirely of concentrates can be successfully smelted, thus saving the cost of briquetting or nodulising.

The experiments at Sault Ste. Marie, referred to above, demonstrated that it was possible in the electric furnace to produce iron with low contents of sulphur, from ores containing large amounts of that unwelcome element. Whilst this point has not been confirmed on a large scale at Trollhattan, owing to the fact that high sulphur ores are not mined in Sweden, yet there is no doubt that the electric furnace, permitting as it does the use of very high temperatures and exceedingly basic slags, is admirably suited for smelting sulphurous ores. Owing to the fact that fluid slags with high lime contents can be maintained in the electric furnace, ores containing considerable percentages of titanic oxide can be successfully smelted without difficulty.

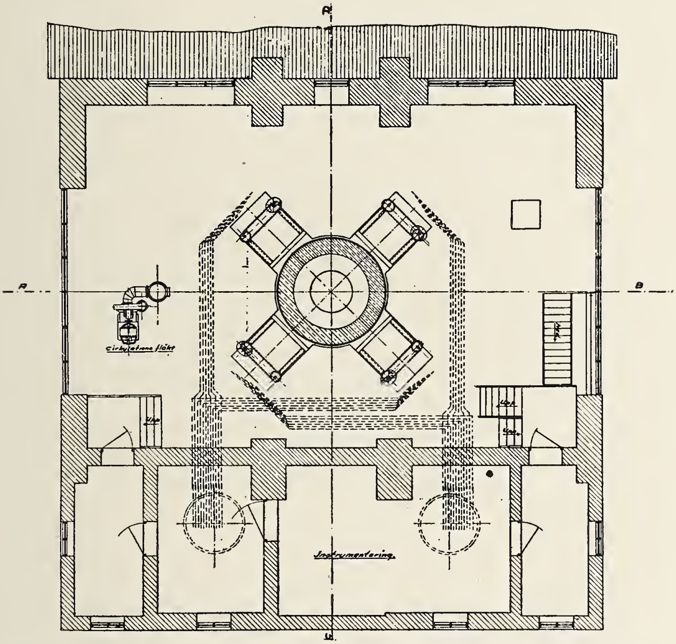


Fig. 4—General plan showing connection between Transformers and Furnace

The quality of the pig iron produced in Sweden has been subjected to severe tests, and, further, has been converted into steel in open hearth furnaces, which steel was then tested against similar steel made from charcoal blast furnace pig iron. The tests showed that the quality of the new product was in most cases equal and in some cases superior, to that produced by the older methods.

The development of the electric furnace from the early experimental stage up to the present state of efficiency has been extremely rapid, and in view of the widespread interest which its successful working has aroused, there can be little doubt that many more electric smelting furnaces will be erected during the next few years.

GRADUATES IN NEW YORK

The University of Toronto Club of New York held its tenth annual banquet on the evening of February 10th. Some seventy graduates of the University were present at the gathering. Professor Wright and Professor Alexander were in attendance as representatives of the University staff. In addition to them there were seated at the head table the presidents of the New York societies of McGill and Queen's, Alexander B. Humphrey, secretary of the American Peace and Arbitration League, and others. Among the graduates in Applied Science and Engineering who attended are noted the names of T. Kennard Thomson, Eugene W. Stern, H. F. Ballantyne, L. L. Brown, H. V. Serson, A. G. MacKay, Douglas Mackintosh, and H. P. Rust.

Mr. Walter H. Robinson, who was for many years the leader of the University of Toronto Glee Club, was present and added much to the evening's enjoyment.

The reunion was held in the banqueting hall of the Engineers' Club, on Fortieth Street.

Geo. K. Williams, '10, is in the employ of the Dominion Bridge Co., Montreal.

C. W. Connell, '11, and L. E. Jones, '11, are in the office of the City Engineer, Vancouver.

J. H. Ryckman, '06, is in the construction department of the Rock Island Railway, Chicago.

F. M. Byam, '06, formerly with Smith Kerry & Chace, in their Toronto office, has become associated with the firm of McGregor & McIntyre, Toronto.

W. G. Turnbull, '09, is the chief engineer of the Turnbull Elevator Company, whose headquarters are in this city.

L. C. Mitchell, '11, is employed in the chemical laboratories of the Guantanamo Sugar Company, Cuba.

C. A. O'Gorman is on construction work for the Canadian Northern Railway at Carillion, Quebec.

THE ANNUAL DINNER

As a medium of controversy and communication between the University and the industrial forces outside, this twenty-third annual reunion of the graduate and student members of the Engineering Society accomplished its object in the usual successful manner. For their splendid management and enthusiasm, to the members of the executive is due a good measure of thanks, and as an event to reflect upon, they should feel justly proud. For a number of years the dinners have been the means of increasing intercourse between this institution and Canadian commercial corporations. To recapitulate, last year the guest list included a hundred or more members of boards of trade throughout the province. The representation was admirable and the widespread interest outgrowing from the event could not have been otherwise than beneficial. In 1910 the Canadian Manufacturers' Association were invited and were present in large numbers. Dr. J. A. MacDonald, Mr. P. W. Ellis, and Mr. J. P. Murray were among those who added fuel to the awakening interest in Canada's industrial education problem. Three years ago the Canadian Society of Civil Engineers, about two hundred strong, were guests of the Engineering Society. This brilliant occasion, which was the largest dinner in the history of the institution, is very fresh in the memory of all who were present. And so on. The first annual dinner, on January 31st, 1890, with its total of fifty-four, has had its repetitions yearly, each evidencing the deeply-rooted loyalty of every School man to his Alma Mater, his interest also in the outer world, and its interest in him. As the anniversaries accumulate in the annals of the School, the term "outside" on the one hand, and on the other the term, "highbrows on College Street" are each llosing all sense of significance, and a bond of union is steadily assuming the place. The relation is still exceedingly small in comparison with what it will be when it is more universally realized that the University aids industrial and commercial progress in a manner no other influence can. The strides are ever in the right direction, and the product of academic training is the force that is foremost in completing the span. The dinners of the Engineering Society have thus an assigned function, and the problem that yearly taxes the ingenuity of its executive officers is the utilizing of the opportunity to the very best advantage.

This year Mr. McPherson and his men displayed excellent judgment in inviting to their dinner the Commission of Conservation. At no time other than the present has there been the universal interest attending the conservation of Canadian resources. Too many tales are truthfully told of the economic waste in other countries. Neglectfulness and lack of national foresight has cost many their best assets to strength and prominence among the nations of fifty years hence, and the results were grim in outlook when conservation measures were first enforced in some lands. Canada's Commission of Conservation, in its three years of active service, and in its service to come, are storing up volumes of prevention against such conditions here. Their work merits the praise and approval of every domain, and all domains deign to keep an admiring eye upon the transitions of this young country. The Commission is merely an advisory board, depending upon the co-operation and support given it by public opinion, and by the adoption of its recommendations, yet the work of the Commission thus far has been effective to an exceedingly satisfactory degree. The investigations in forest preservation, lands, mineral resources, fisheries, town-planning and housing, water and water powers, are among those which already show remarkable results in the comparatively short duration of time in which the committees have been in operation.

Not all the members were able to be present. The Commission opened its third annual session in Ottawa just several days previous and a number were detained. From those who were with us, however, a valuable summary of the aims and accomplishments was obtained, the work already done, that to do, and the parts requiring the skill of the engineer. Upon them was impressed, at the outset, the School man's appreciation of their endeavors, his realization of the necessity for deepest investigation, his exuberant co-operative spirit, and his aim to become a factor in the manipulation of the economic advantages of the Dominion to the best possible service.

We must not omit the fact that among our guests the most worthy of note are the graduates whose interest in society and school affairs brings them back to enjoy the evening in a manner well known to them. Approximately twenty per cent. of those present were graduates. We wish we could speak so highly of the undergraduate attendance. The men of the fourth year were the ones to take most advantage of the dinner. It appeals to them, as to the graduates, as an opportunity for associating with the stamp of men in whom it behooves them, as engineers, to be vitally interested. Some 42 per cent. of the fourth year were participants. The other years were considerably below any such percentage.

The banquet hall was beautifully and appropriately decorated for the occasion. A huge shield on the west wall standing in the centre of a general scheme of yellow, blue and white, interspersed throughout the whole surface of the wall with smaller shields and flags, bore the inscription, "The Faculty of Applied Science Welcomes the Commission of Conservation." The orchestra occupied an elevated platform on the opposite side of the hall. The orchestra is this year an innovation into the social life of the Science man, and the applause which it meritoriously received throughout the whole proceedings, indicated that there was a place for it, and that the place was being filled exceedingly well. Mr. Temple and his "Toikey-Oikestra" allowed not a dull moment to come into being, from the opening till the closing of the doors. The octette, as usual, surpassed itself in its rendering of a number of catchy selections. This year its personnel is made up of Messrs. Mickler, Chandler, Skinner, Macauley, Blackwood, McLean, Foote and Fansher. The presence of these two musical organiaztions in the school is viewed with considerable pride by old graduates, as well as the student body. That they fill a vacancy at the annual dinner was clearly in evidence.

The repast concluded, Mr. McPherson welcomed the guests in a short but extremely appropriate address. His toast to the King received the usual response of the School man. He then asked Mr. E. R. Gray to propose the toast to the Commission of Conservation of Canada, to which Mr. M. J. Patton, who attended by the special request of Hon. Clifford Sifton, he himself being regrettably prevented from being present, responded.

Mr. Patton expressed his pleasure in having the opportunity of speaking to an audience of engineers. Although this was the first time he had had the privilege of being with them he was inclined to feel quite at home because he was conscious of the fact that they were both co-workers in the same cause. The material with which both had to do was the natural resources of the country, and both were interested in seeing that the people of Canada got as much enjoyment out of the development of these resources, with the least exertion of effort, as it was possible for them to do. Conservation meant economical development, its search was for efficiency in utilization; and the whole training of the engineer made for efficiency. Any rough and ready handy-man could put together some kind of a water-wheel that would develop a small percentage of the power in a waterfall; but only a trained technical man could design a turbine that would utilize 80 per cent. of the energy from the water that tumbled over the fall. The mining engineer was likewise trying to devise methods of taking ore out of the earth with a minimum of waste, and, in similar ways, the civil, the electrical and mechanical engineer were endeavoring to get the maximum use out of the powers and stores of nature with the expenditure of the minimum effort. In their strivings for the elimination of waste and the realization of the highest efficiency in developing the natural resources of Canada, the engineer and the conservationist were as one.

Because of his efficiency in the line of his chosen work the engineer was looked up to as an authority in these things by the rest of the community. He therefore exerted an influence of no mean power upon public opinion in respect to the methods of developing natural resources; and, in exercising this influence in the proper manner, he could be of inestimable service to the work of conservation. For the conservation movement, as organized in Canada, depended entirely upon the support of public opinion for its success. The Commission of Conservation was merely an advisory body, whose efficiency depended upon the accuracy and justness of its decisions and on the thoroughness of its investigations. It was entirely non-political, and had no powers of administration whatever. Great importance was therefore attached to its ability to command public support. Its members consisted of financiers, farmers, lumbermen, engineers, educationists, in fact, prominent men drawn from all vocations, and in its ex-officio members the Dominion Government and all the Provincial Governments were represented. It was therefore in a position to promulgate its findings widely. Furthermore, it made much use of the press in spreading the propaganda of conservation, and its publications were attractively gotten up and widely distributed.

Sometimes, it might happen that the public were not far enough advanced to appreciate fully some of the policies advocated by the Commission. The task, in such a case, was to educate the people up to these projects. When a government was convinced that the people wanted a certain thing done, it never hesitated in meeting their wishes.

In the moulding of public opinion along well-defined lines of conservation, the engineers of the country, on account of their positions of authority could do much. Indeed, the Commission of Conservation had very much to thank them for already. The Canadian Society of Civil Engineers had formed a Committee on Conservation that was of very great assistance in the collection of information, and the "Water Powers of Canada," recently published by the Commission, was made possible largely through the kindness of engineers from one side of Canada to the other, in furnishing data regarding the powers of which they had knowledge.

He wished to refer to only two of the many concrete subjects concerning which public opinion needed to be definitely moulded at the present time. One of these was the utilization of peat as fuel. Up to the last year or two, no method had been found which was commercially feasible for separating the moisture from peat to such an extent as to make it useful as a fuel. Investigations had, however, been carried on by the Mines Branch of the Department of Mines, which had demonstrated beyond any reasonable doubt that peat fuel could be produced on a commercial basis to compete with coal. The fuel testing plant of the Mines Branch at Alfred had turned out 3,000 tons of peat, which had been eagerly bought by the people of Ottawa. The cost of production at the bog was $2.25 per ton, and to this was added 90c. for freight and 10c. for delivery, making a total of $3.25 per ton to the consumer. As 1.8 tons of peat were equal in fuel value to one ton of anthracite, the saving in price was evident wherever coal had to be hauled a long distance.

The demonstration of the fact that peat could be produced to compete successfully with coal was of immense importance to the provinces of Central Canada, who were dependent mainly upon the mines of Pennsylvania for their supply of fuel. There were large deposits of peat in Canada. So far as was known at present there were 37,000 square miles of peat bogs in this country, ranging in depth from 5 to 10 feet. In Ontario alone, there were 10,450 square miles, 450 of these being in settled parts. The significance of this could be appreciated when it was known that one cubic yard of bog produced about 250 lbs. of burnable peat.

There were, of course, certain interests who would not benefit in having peat seriously compete with coal as a fuel, and these, of course, were not particularly anxious to see the process of peat manufacture perfected to a higher degree than it now was. It was, therefore, incumbent upon all public spirited citizens who knew the facts to make it known that it was now possible to produce peat on a commercial basis, and it was their duty to endeavor to create a public sentiment that would favor the further perfecting of the present process of peat manufacture.

Another matter that the public should be made to realize was the enormity of our fire losses and the possibility of lessening them. Last year in Canada they amounted to twenty-one and a half million dollars, and, as a rule, averaged yearly from $2.95 to $3.00 per head of population. The average per capita loss in Germany was 49 cents; in France, 30 cents; in Austria, 29 cents, and in Italy only 12 cents. The three main causes of our large fire losses were usually given as climate, carelessness and construction. We could not make out winters warmer, but an educational campaign against carelessness could do much to lessen the number of fires due to our cold climate. In many of the states of the United States the methods of fire prevention were taught in the public schools and fire marshals were appointed to lead the fight against excessive fire losses. In a number of the states the fire marshals had justified their appointment by reducing the fire losses, and, as a natural consequence, the insurance rates. The most fruitful cause of fires, however, was the bad municipal building by-laws and their bad enforcement. In a new country it was natural that many flimsy structures would be erected, but Canada was getting old enough now to remedy this hazardous condition.

The majority of municipalities seemed quite incapable of enforcing even the kind of building by-laws they had. The last census had shown that 45 per cent. of the population of Canada was grouped in towns and cities, and, in view of the demonstrated incapacity of municipal authorities dealing with the important problems within their purview, it would be a wise thing for the Provincial Governments to consider seriously the advisability of creating Departments of Municipal Affairs to exercise a close supervision over the solution of those problems incident to the crowding together of people in centres of population.

"The success of the graduates, all over the civilized, and in the case of our faculty, the uncivilized world, is an indication of the influence of the University," said Mr. G. B. Taylor, '14, in proposing the next toast, that to the University, to which Dr. Ellis, after a perfect storm of acclaim, responded.

The doctor dwelt upon the growth of the University, under the influence of Canadian atmosphere, activities, aims and anticipations. He exemplified the influence by comparing the growth with that of the tree just east of the main building. A European maple was grafted upon a Canadian stock. Both flourished. Eventually the Canadian branches superseded in development the added branch. The difference in robust growth and strength increased, and at the present time the tree is a truly Canadian maple, the life of the European having been entirely assimilated, and the product a thorough native. Doctor Ellis' unique illlustration of the effect of surrounding forces strikingly impressed his audience, especially the younger men, many of whom had not seriously considered before the creative influence embodied in their associations with University factors in the present and future.

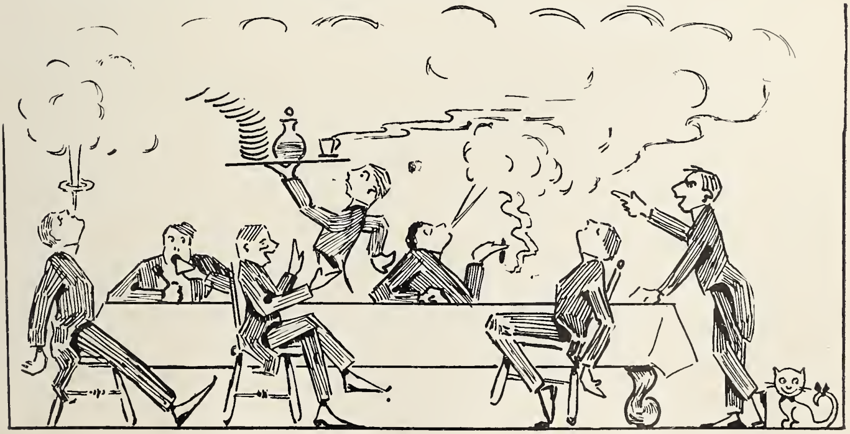
Mr. R. J. Fuller, '11, proposed an impromptu toast to the newly-appointed Professor of Metallurgy, Prof. G. A. Guess. The difficulties experienced in locating a capable head for this department, and the qualifications possessed by the man who, as a member of the staff, was in attendance for the first time at the annual dinner, were well brought out. The great welcome tendered to Professor Guess at the close of Mr. Fuller's remarks bespoke the universal appreciation of the whole assembly. In a few words of reply, the newcomer expressed with what deep feeling he accepted the welcome of the staff and students.

Mr. J. S. Galbraith, '13, proposed the toast to "The Professors." The burden of responsibilities which the young engineer was taking upon him were none too great for the men from the School to cope with. Aptly he mentioned "The School man, of course," as the engineer of to-day.

Mr. W. F. Tye, in responding, viewed with pride the engineering education obtainable in the Faculty of Applied Science. Since his student days he has kept closely in touch with University affairs. He pronounces the progress as being of the best. He dwelt reminiscently upon the joys and trials of the early days in S. P. S., and upon the influences which commence, when a man leaves college, to mould into shape the engineer-to-be. The status of the engineer to-day is vastly different from that of years ago, when a college education was deemed more of a hindrance than of a benefit when in quest of a position. Now the tables are reversed, and in this age of the engineer the technically trained man has an unsurmountable advantage over the so-called practical man. Mr. Tye gave as his best advice to the undergraduate an intimation that had been brought home to him repeatedly in this thirty years of graduate work, that of making and preserving a careful collection of cost records of all work with which one is connected. Efficiency engineering is common to all branches of the profession. It is vital in its importance, and commands the fullest consideration. No man can do better than to begin right by observing, as all may, the cost data connected with whatever work in which he may be employed.

Dean Galbraith also spoke, commenting upon the success of the event, and upon the work the Society was accomplishing. "This is one of the most successful dinners that the Society has ever held. I am in a position to know. This is the twenty-third for me."

Mr. J. B. Tyrrell, a graduate of nearly thirty years, whose professional duties has prevented him from attending many of our dinners, and whose efforts to be present were on this occasion fortuned with success, was enthusiastically welcomed, and his brief address most warmly received.



TESTS ON THE STRENGTH OF NAILED JOINTS

J. H. Thornley, B.A.,Sc., '08

In this day of steel and concrete, a discussion of anything pertaining to timber construction may seem somewhat out of place, but to the Canadian hydraulic engineer at least timber is still a building material of prime importance.

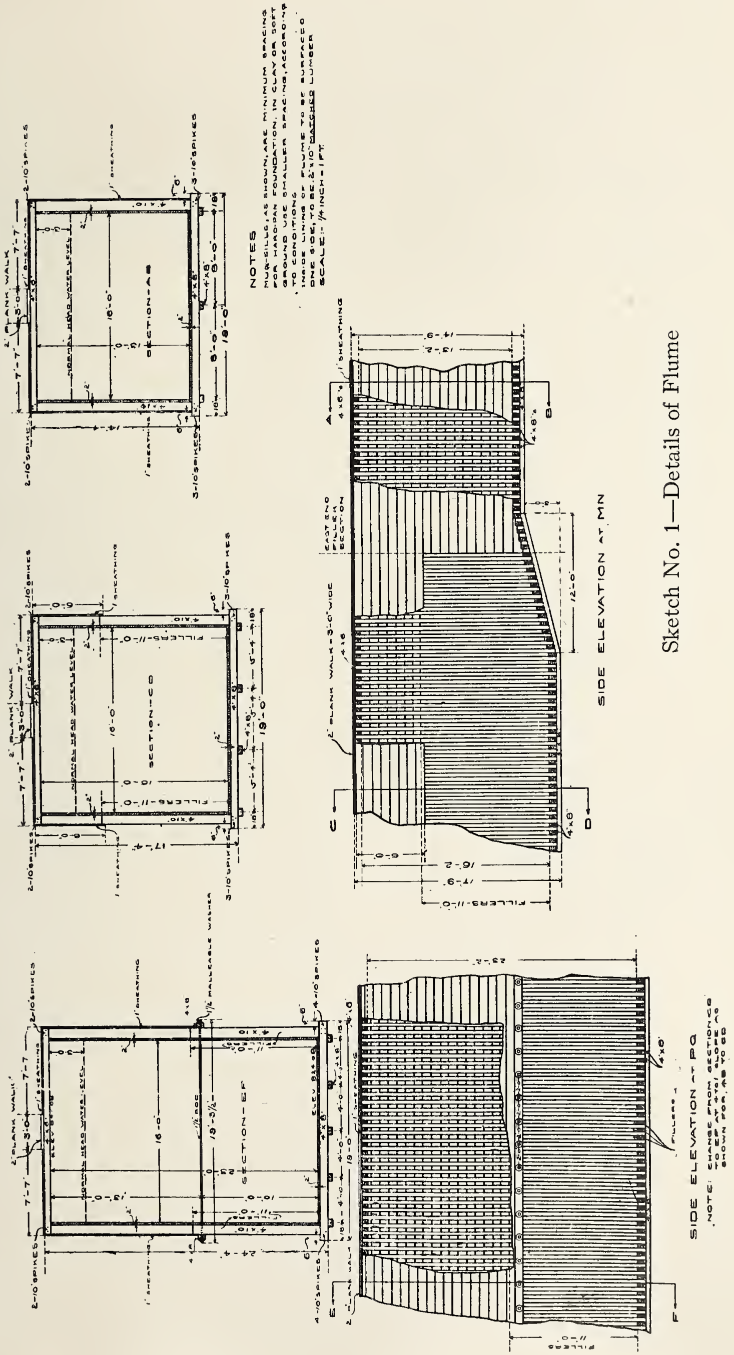
The brief nail test here reported was made in connection with the design of the Porcupine Power Company's Hydro-Electric plant at Sandy Falls on the Mettagami River, built by Mr. H. D. Symmes, of Niagara Falls, Ontario.

A word or two regarding this plant may be in place since the qualities sought in the joints tested can only be understood by a consideration of the special construction conditions.

Since the generating plant, a 4,500 h.p. hydro-electric station, was at the time of construction more than forty miles by bush road from the nearest station, and since it was essential that the plant should be constructed with the utmost speed, it was desired to cut to a minimum the use of steel, concrete or other bulky materials requiring to be brought in from the railroad. It was, moreover, desirable to use none but the simplest timber construction on account of the difficulty of turning out carefully sized lumber from a temporary sawmill, and also because it was the intention to avoid labor trouble by using lumberjacks rather than carpenters for the bulk of the work,—an obvious impossibility on work demanding careful framing.

A rock filled corn crib and stop log dam and timber power house would satisfy conditions both in the matter of construction and material, but the flume offered difficulties. The standard types demanded a great deal of steel in the form of bolts and tie rods and the use of these bolts and rods demanded a fair average degree of skill, in the gangs erecting the work. Finally, after getting out several designs, that shown in Fig. No. 2 was suggested. As will be noted, the construction consists of a corn crib, such as is used in a crib and stop log dam, only that in the case of the flume the crib is turned on its side and sheeted on the inside instead of the outside. This construction called for the use of a minimum of steel, and since practically no skill was needed beyond the ability to drive nails, the flume could be built by lumberjacks quite as well as by carpenters. The one question in doubt was that of the possibility of constructing a nailed joint sufficiently strong to withstand the hydrostatic pressure. It was to determine this point that the tests, the results of which follow, were run.

The accompanying photographs, Nos. 1 and 2, show the flume under construction. The gang shown in the first picture, all lumberjacks, erected the framework of the flume at an average rate of a little better than one hundred feet per day of twelve working hours. The flume, which has been carrying water for some time now, seems to be giving satisfaction.



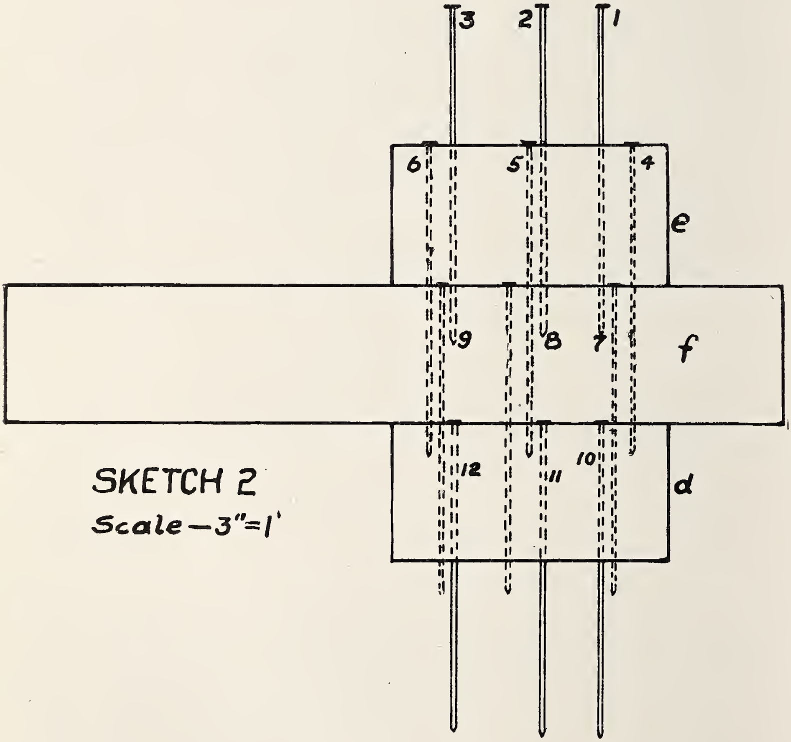
Sketch No. 1—Details of Flume

Purpose of Test

To ascertain the transverse holding power in pine lumber of nine-inch spikes (4½ to the pound), and in particular to find the permissible load on a nailed joint as used at lower corner of a corn crib flume of construction as shown in Sketch No. 1, and to find what nailing will give maximum strength for such a joint, that is, to find a nailing with which failure will be equally likely to occur by cracking of the timbers or by drawing of the nails.

Three characteristics of any timber joint of great importance are:

(1) Relation of elastic limit to ultimate load.



SKETCH 2
Scale—3"=1'

(2) Extreme permanent deflection possible without lessening of ultimate strength. This point is of prime importance since, owing to the inequalities in size of commercial lumber, more particularly in unplaned material and to unavoidable inaccuracies in work fabricated by carpenters, joints are often called upon to undergo very considerable deflections before the theoretical distribution of loads occurs.

(3) Effect of moisture and frost. The present test would have no bearing upon this point.

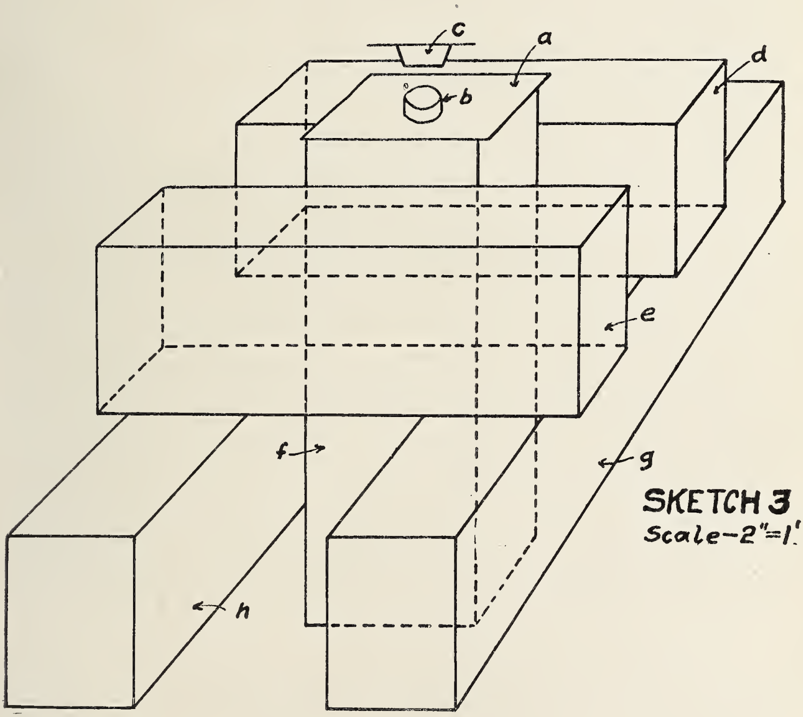
Method of Test

The specimen was made by nailing together three pieces of 4 in. x 8 in., 4 in. x 10 in., 3½ in. x 8 in., or various combinations of these sizes, as shown in sketch No. 3.

Sketch No. 2 shows the nailing used for the most of the tests.

Sketch No. 1 shows the nailed joint as used in the flume.

In Sketch No. 3—



SKETCH 3
Scale—2"=1'

"A" is a ½-in. steel plate used to distribute the load applied to the end of the 4 in. x 8 in. piece marked "F."

"B" is a universal head of the ball and socket type.

"G" and "H" are piles of blocking.

"C" is a wedge-shaped piece of steel attached to the upper or movable head of a one hundred ton testing machine.

In several of the experiments the universal head "B" was dispensed with and the load applied directly to the steel plate "A." This had no apparent effect on the results.

Analysis of Nailing in Accordance with the General Laws, as Deduced from Previous Experiments

Referring here to Sketch No. 2, which represents a joint at the lower corner of a 13 ft. x 16 ft. section of the flume, the effect of nails Nos. 1, 2, and 3 on the elastic limit load of the joint is obtained thus:

Since "grip" has no effect on elastic limit of joint, the elastic limit load of nail No. 1 should be $Cd^2 = 5500 \times (\frac{3}{8})^2 = 770$ pounds. The effect on the ultimate load of the joint will be $2Cd^2 \times \frac{\text{grip}}{\frac{1}{3}\text{ length of nail}}$ $= 2 \times 5500 \times \frac{9}{64} \times \frac{1}{3} = 518$ per nail if failure result from drawing of the nails.

The effect of nails Nos. 4, 5, and 6 on the elastic limit of joint must be considered for the points "A" and "B". Each nail will be effective at these points. Elastic limit load on No. 4 $= Cd^2 \times 2 =$ $5500 \times (\frac{3}{8})^2 \times 2 = 1540$ pounds. The ultimate load of No. 4 at "A" will be 1540 pounds and at "B" 513 pounds.

Each of Nos. 7, 8, and 9, will effect the elastic limit load to the extent of 770 pounds and the ultimate load to 1540 pounds.

Nails Nos. 10, 11 and 12 will have no effect on either the elastic limit or the ultimate load of the joint, except as they may effect a possible failure by cracking of the timbers.

Theoretical Elastic Limit Load of Joint as Shown

From No. 1, No. 2, No. 3	2310
From No. 4, No. 5, No. 6	4620
From No. 7, No. 8, No. 9	2310
From No. 10, No. 11, No. 12	0000
	9,240

Theoretical Ultimate Load of Joint as Shown

From No. 1, No. 2, No. 3	1540
From No. 4, No. 5, No. 6	6160
From No. 7, No. 8, No. 9	4620
From No. 10, No. 11, No. 12	0000
	12,320

Summary of Results of Previous Experiments Bearing on Strength of Nailed Joints

In as far as could be ascertained, no experiments have been made on the transverse strength of the nailed joints made with nails larger than 60d. (6 in.), but from experiments with 60d. and smaller sizes of nails the following general laws have been deduced:—

1. Permissible deflection of a nailed joint 1-16 in. for 60d. nails.

2. Elastic limit of joint will be one-half ultimate strength.

3. Strength of joint is directly proportional to the number of nails used and is independent of relative position of nails when failure does not occur by cracks in timber.

4. The holding power of a nail at the elastic limit is expressed by the equation Cd^2 where C is a constant dependent on the material (5500 for pine, fairly dry) and d. is the diameter of the nail in inches ($\frac{3}{8}$ in. for 9 in. spikes 4½ to the pound). This holding power is independent of the length of the grip (that is, that part of the nail between the point of application of a shearing load and the point of the nail). It will be noted that according to this equation the elastic limit is entirely dependent upon the material, under a crushing load of the timber.

Fig. 1—Porcupine Power Co.'s Flume under Construction.

5. The holding power of a nail at ultimate load varies directly with the length of the grip up to a grip of one-third the length of the nail when it becomes practically constant and is expressed by the equation,

$$\text{Ultimate load} = \frac{2Cd^2 \times \text{grip}}{\text{1-3 length of nail}}$$

In consideration of the fact that wooden joints show a deflection of an inch or more before reaching ultimate load, a brief study of

TABULATED RESULTS

DESCRIPTION OF SPECIMEN.				Load in pounds at which first signs of failure were noted.	Load in pounds at ultimate failure.	Number of 100% effective nails equivalent to nailing as used. Equation-Ult. L = grip / 1-3 length	Number of 100% effective nails equivalent to nailing as used. Equation Ult. L = grip / 1-3 length constant.
Number.	CONSTRUCTION. NOTE: See Sketch No. 3.	METHOD OF NAILING NOTE: See Sketch No. 2	REMARKS ON LUMBER USED				
1.—	D. & E: 4 in. x 10 in. F: 4 in. x 8 in.	8 NAILS 2 to each piece of specimen	Pine rough. Fairly dry. Material fair	8200	9500	5 1-3	6
2.—	D & E: 4 in. x 10 in. F: 4 in. x 8 in.	12 NAILS 3 to each piece of specimen, driven as indicated in Sketch No. 2	Pine rough Fairly dry Good condition	14000	15960	8	10
3.—	D & E: 4 in. x 10 in. F: 4 in. x 8 in.	16 NAILS 4 to each piece of specimen, driven as indicated in Sketch No. 2	Pine rough Fairly dry Good condition	19000	21000	10 2-3	13 1-3
4.—	D, E & F: 3½ in. x 8 in.	12 NAILS 3 to each piece of specimen, driven as indicated in Sketch No. 2	Pine planed Fairly dry Fair condition	12000	16070	10	12 2-3
5.—	D, E & F: 3½ in. x 8 in.	8 NAILS 2 to each piece of specimen	Pine planed Fairly dry Weather cracked	9840	11550	6 2-3	8
6.—	D, E & F: 4 in. x 8 in.	12 NAILS 3 to each piece of specimen, driven as indicated in Sketch No. 2	Pine rough Fairly dry Fair condition	14400	16350	8	10
7.—	D, E & F: 4 in. x 8 in.	12 NAILS 3 to each piece of specimen as in Sketch No. 2	Pine rough Fairly dry Fair condition		16000	8	10
8.—	D, E & F: 4 in. x 8 in.	9 NAILS 3 Nails with 1 in. hold omitted	Pine rough Fairly dry Extra Good material	13000	16500	7	8

NOTE:—Observations of Elastic Limit Load were entirely unsatisfactory since the specimens showed large permanent deflections under the first 25% or less of the load but even when the specimen had been stressed almost to the point of failure with corresponding deflections of an inch or more the load could be released and again brought about above the previous high point without causing any material increase in deflection beyond that which had resulted from

OF EXPERIMENT

Observed average ultimate load in pounds per 9 in. spike 100% effective. Equation: $L = \frac{\text{grip}}{\text{1-3 length}}$	Observed average ultimate load in pounds per 9 in. spike 100% effective grip Equation: $\text{Ult. } L = \frac{\text{constant}}{\text{1-3 length}}$	Calculated ultimate load per 9 in. spike 100% effective. Equation: Ult. $L = 2\,Cd^2$	Calculated load elastic limit in pounds. Equation: El. $L = Cd^2 \times$ No. nails. No consideration taken length grip.	Observed load in pounds at elastic limit of joint.	REMARKS
1770	1580	1540	6160	See Foot Note	The values of the joint are the values as governed by the nails
1990	1590	1540	9240	" "	The values obtained are the values of the joint as governed by the nails for in this case failure resulted from the drawing and bending of the nails.
1950	1570	1540	12320	" "	The values observed are the values of the joint as governed by the nails for in this case failure took place by the drawing and bending of the nails.
1600	1320	1540	9240	" "	The values obtained are the values of the joint as governed by the wood for in this case failure resulted from the cracking of the nails of the piece lettered "E" in Sketch No. 3.
1750	1440	1540	6160	" "	Failure as in No. 4.
2040	1630	1540	9240	" "	The values obtained are the values of the joint as governed by the wood for in this case failure resulted from the cracking of the nails of the piece lettered "E" in Sketch No. 3.
2000	1600	1540	9240	" "	The values of the joint are the values as governed by the nails since in this case failure resulted from the drawing of the nails, therefore 1600 represents the holding power of the nail.
2360	2060	1540	6930	" "	The results from this specimen, as will be noted, show very poor agreement with the other theoretical values or with the observed values of the other seven specimens. This is probably, in part at least, a result of the extra good lumber used. It is included as showing a probable limiting maximum value for the nails

Sketch No. 2 would suggest that the ultimate load on the joint shown must be taken up by the nails in two ways.

(a) By a resistance to withdrawal from the wood.

(b) By a bending of the nail resulting from the shearing force and the resistance to crushing of the wood. Since nails with a grip of an inch or better are bent into very similar curves, this second element does not vary with the grip but is constant. A more reasonable equation for ultimate load for a nail as governed by grip would appear to be

$$\frac{(2\ Cd^2 \times \text{length grip plus } X \text{ times } Cd^2).}{\text{1-3 length nail}}$$

The value of X as assumed in these experiments was two-thirds. It

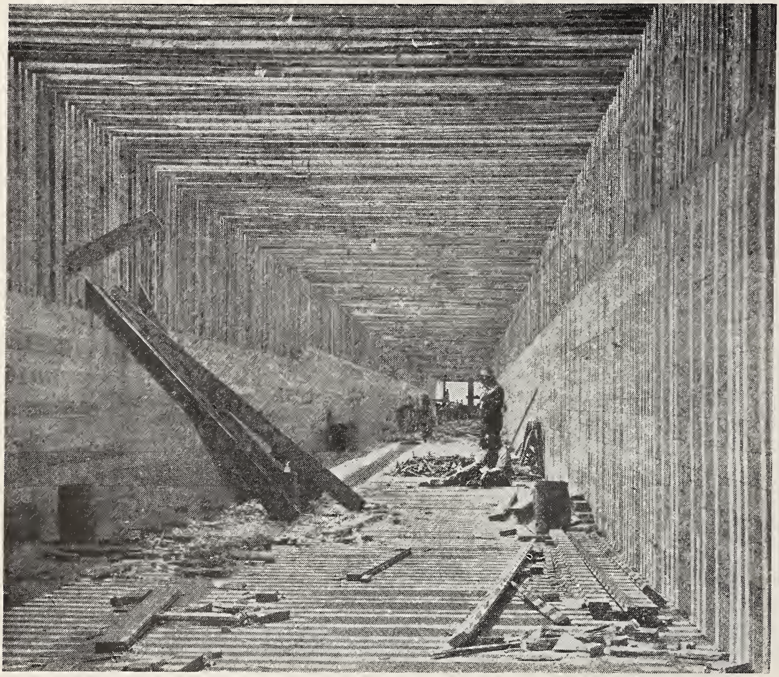


Fig. 2—Showing Flume Nearing Completion.

will be noted that the value of this expression is dependent upon the modulus of elasticity of the timber and the steel in the nails.

Notes on Results of Experiment

To design a well proportioned joint it was necessary first to ascertain the laws governing the holding power of a 9 inch spike in cases where the failure took place by drawing of the spikes, that is, to find the value of one spike, and second to find the limiting number of spikes which would develop their full load value (that is, would not cause failure by splitting) in a joint made up of 4 in. x 8 in. pieces. The 8 in. dimension was fixed by the load on the side of the flume under consideration.

Specimens Nos. 1, 2, and 3 were made with 4 in. x 10 in. used as cross pieces (failure by cracking would occur in the cross pieces if at all) and with two, three and four nails per piece respectively. In every case the failure of the joint took place in the nails, and since the results were quite uniform (1580, 1590, 1570 average per nail respectively) it may reasonably be concluded that these values would hold for 9 in. spikes in pine regardless of the dimensions of the timbers.

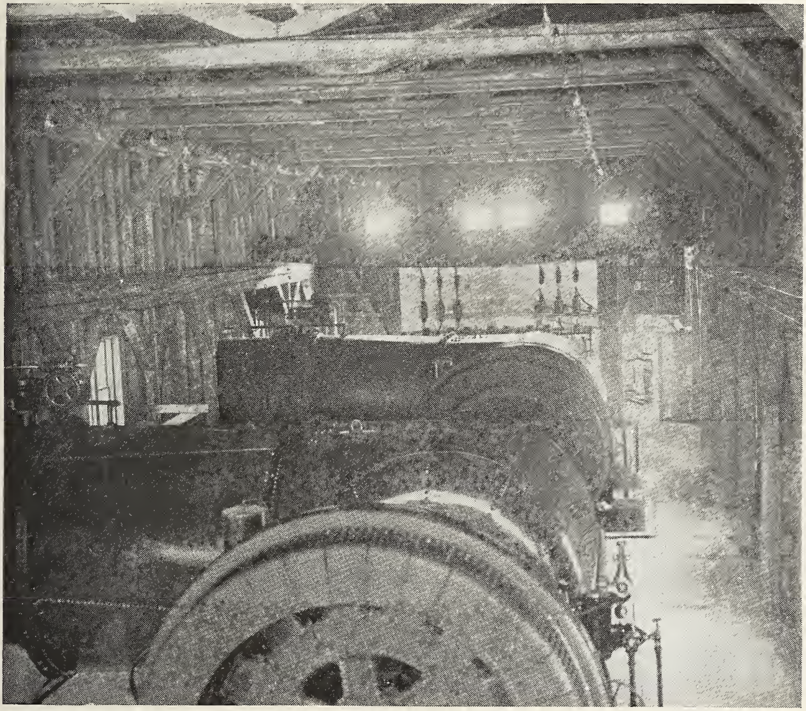


Fig. 3—Interior of Porcupine Power Co.'s Generation Station, Showing Units No. 1 and No. 2

In experiments Nos. 4 and 5 the number of nails was as before, but the timbers were reduced from 4 in. x 10 in. to 3½ in. x 8 in. Failure occurred at a much lower value per nail than with the 4 in. x 10 in., which would suggest a failure of the timbers, this was in agreement with the observations.

In experiments Nos. 6 and 7 the nailing was as before, but the timbers were of an intermediate size 4 in. x 8 in. Failure occurred at about the same average load per nail as in experiments Nos. 1, 2 and 3, but while in No. 6 failure occurred by breaking of the timbers, in No. 7 the failure was due to bending and drawing of the nails. The proportioning of nails to timber was, therefore, about correct.

Omitting experiment No. 8 and averaging the values of a 9 in. spike as found in the remaining four experiments where failure took place by drawing of the spikes and using number of nails as found by equation, $\frac{\text{grip in inches}}{\text{1-3 total length}}$ – const. , we get 1570 as ultimate load value in shear of 9 in. spike in pine, as against a theoretical value of 1540 pounds. The greatest divergence of a single experiment from the average was 60 pounds.

Supposing the effect of the relation of grip to total length to be as suggested by Merriman, that is, the efficiency of the nail varies as $\frac{\text{grip in inches}}{\text{1-3 total length}}$ up to a grip equal to 1-3 of the length, the average value of a nail as found by the experiments would be 1920 pounds, and the greatest variation from this shown by any experiment would be one hundred and fifty pounds.

Therefore the equation introducing a constant for the effect of the bending of the nails seems, both from the standpoint of theory and observation, to be somewhat the nearer to the truth, though the experiments were far too few in number to in any sense settle this point. The constant assumed, 2-3 Cd^2 where C for the lumber used = 5500, and d = diameter of nail in inches, was in all probability somewhat excessive.

In the light of subsequent experience in actual field construction, the writer would judge that the value of C should be, for commercial grades of pine, somewhat higher than 5500, while the fraction two-thirds might with advantage be reduced to one-third or less.

Adverting to the summary of the results of previous experiments:

(1) The permissible deflection value of 1-16 inch, that is, deflection which can be caused without weakening the joint, is altogether too small. Joints tested to deflections of an inch and more seemed to be in no way weakened. This is a very strong point in favor of the nailed timber joint.

(2) As has been pointed out, no satisfactory results were obtained regarding the relation of elastic limit to ultimate load. The percentage relation of elastic limit to ultimate load would depend on the definition assumed of elastic limit, but for practical purposes there can be no doubt that it is at least fifty per cent.

(3) The relation stated between the strength of a joint and the number of nails used, that is, that strength of joint is proportional to number of nails and entirely independent of arrangement of nails where failure does not occur by cracking of the timbers, was entirely borne out by the experimental results. Various arrangements of the nails were tried, the nails of almost every specimen being differently spaced, but as will be noted, no material difference in holding power resulted.

INSTRUMENT TRANSFORMERS AND THEIR COMPENSATION.

By Harold A. Cooch, B.A. Sc.

Voltage Transformers.

The measurement of high voltage is a problem which is taken care of usually by two or perhaps three methods—

(*a*) Spark gap method.

(*b*) Electrostatic voltmeter.

(*c*) The use of a small transformer to step down the voltage to a standard which is usually about 100 volts.

The object of this paper is to exemplify a few important facts concerning transformers for meter service.

Voltage transformers are subject to the effects of regulation similar to any other transformer, although, generally speaking, the effect is not so noticeable, due to the fact that their load is small in comparison to their total capacity.

Since the accuracy of the ratio depends on the regulation it is therefore apparent that where accuracy is essential, especially in determining voltages as sent out from a power plant, it is necessary to design a voltage transformer with a comparatively small drop in voltage for ordinary loads. For this reason it is customary to work the copper at a very low value, which ranges usually between 1.5 to 2 watts per lb. Distributing transformers are usually worked at about 4 watts per lb., while large water-cooled transformers have copper losses of about 10 watts. per lb.

On the operation of wattmeters from commercial sources a slight difference of phase between primary and secondary voltages and currents will render quite a change in the wattmeter readings, and is also therefore an important item in the design. This phase displacement between primary and secondary is due to the exciting current, and in order to minimize this error we must have our exciting current as low as possible.

Since the exciting current is the resultant of the magnetizing and core loss currents, it is obvious that we must work our iron at a very low flux density, and also design our magnetic circuit with as low a reluctance as possible.

The flux density usually considered in the design is 7,500-8,000 lines per square centimetre, as compared with 10,000-11,000 lines per sq. cm. used in the case of lighting transformers.

The limitation of the reluctance in the magnetic circuit is taken care of by enlarging the section of iron where joints are necessary, and consequently lowering the flux density at these points. The phase displacement in the voltage transformer is then quite small, so that except in special cases it is absolutely neglected.

The object of compensation then in voltage transformers is an annulment of the effect of regulation, i.e., to raise the secondary voltage to such an open circuit value that when load is applied the voltage will fall to the 100% value desired, and is accomplished in either of two ways, or both—

(*a*) Dropping a few turns from H.T.

(*b*) Adding a few turns on the L.T.

The adjustment is preferably made on the high tension winding, be it primary or secondary, due to the smaller effect of each turn.

For successful compensation the voltage, frequency and load on which the transformer is to be used must be known and a transformer compensated for a given set of conditions should not have any of these conditions vary more than 5% either way. Consider now the calculation of this compensation:

(1) Consider the cause of IR drops in the primary winding, P Fig. 1.

I_p, due to the load, is in phase with E_p for a power factor of 100%

I_c, the current necessary to supply the iron losses is in phase with E_p.

I_m, the magnetizing current necessary to magnetize the core to the given flux density is in quadrature I_{ex} is the exciting current required in the primary and is the resultant of I_c and I_m see Fig. 3.

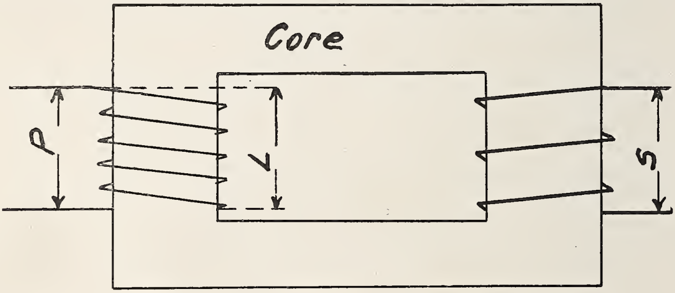


Fig. 1

(2) The load current I_s is the only cause of IR drop in the secondary.

Consider in Figure 3 primary conditions for a load of say 50% *PF*.

To find the drops in voltage in the primary from the above figure:—

We have the following drops in phase with the primary voltage where R_p = Primary Resistance.

1. Drop due to component of load current in phase with the voltage $= I_{p_l} \cos \theta \, R_p$

$$= I_{p_e} R_p$$

where I_{p_e} = the energy component of current.

2. Drop due to the current supplying the core losses $= I_c R_p$
3. Leakage reactance due to I_m, the drop due to this will be in phase with E_p since is it 90° out of phase with I_m and this I_m is already in quadrature with E_p.

To calculate the reactive drop $I_m X$ due to leakage we use the following formula, assuming a core type transformer as in Fig. 1 although the same formula can be supplied to shell type transformers with concentric coils.

$$\text{Reactive Drop} = \frac{210 \times I_m \times T^2 \times f \times r\,(X + Y + 3G)}{10^9 L}$$

Where T = Primary turns
r = mean radius of air gap i. e. between primary and secondary

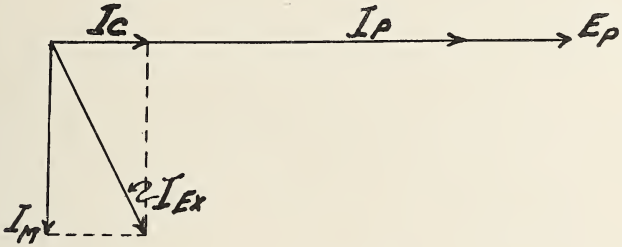


Fig. 2.

f = frequency in cycles per sec.
X = Radial thickness of primary (*H.T.*)
Y = Radial thickness of secondary (*L.T.*)
G = Radial thickness of air gap.
L = Length of coil axially as shown in Fig. 1. (This quantity in the case of coils on two legs must be doubled).

4. The wattless component $I_{p_w} W$ of the load current I_{p_l} produces a reactive drop in phase with E_p and must therefore be considered. For a load of 100% *P.F.*, however, such a drop is not present.

The value of this drop is calculated from the above formula substituting I_{p_w} for I_m and = say $I_{p_w} X$

The drops in quadrature can easily be seen to be:—

1. Reactive drop due to I_{p_e}
2. Reactive drop due to I_c.
3. Magnetizing *IR* drop $= I_m R_p$
4. Wattless component of load current *IR* drop $= I_{p_w} R_p$

To be absolutely correct the resultant of the quadrature and in phase drops should be found and the per cent. calculated, but for all practical purposes (with the exception of very low power factors) only the in phase drops with E_p are considered.

Total in phase drop in primary.

$$= I_{p_l} \cos\theta \; R_p + I_c R_p + I_m X + I_{p_w} X$$

and % drop in primary.

$$= \frac{I_{p_l} \cos\theta \; R_p + I_c R_p + I_m X + I_{p_w} X}{E_p} \times 100$$

The only drop in the secondary winding is that due to the load current.

Let I_s = Secondary current
R_s = Secondary resistance
E_s = Secondary terminal voltage.

$$\therefore \% \text{ secondary drop} = \frac{I_s R_s}{E_s} \times 100$$

Having found the total *percentage* drop in the transformer, this simply has to be expressed in secondary volts to get the desired secondary voltage under required conditions of load.

A concrete example of compensation might be cited as follows:—

A certain power company required a special portable transformer with a H.T. voltage of 2200/1100 for operating relays and recording wattmeters which apparently required exactly 110 volts supplied to them.

Each transformer was to be designed for 100 watts and compensated for 15 watts at 20% Power Factor.

According to calculations the number of *L.T.* turns was 125.

Consequently the number of *H.T.* turns before compensation will be 2500.

On account of the very low power factor (20%) and on account of the accuracy required, the primary quadrature drops had to be considered.

It was not necessary in the *L.T.* on account of the fact that the inductance is low because of the low number of turns.

The following % drops were found:

%drop in *H.T.* in phase with E_p = .18%
% drop in *H.T.* in quadrature with E_p = .218%
Resultant drop in H.T. = .28%
% drop in *L.T.* = .19 at 100% *P.F.*
= .0375 at 20% *P.F.*

∴ Total drop—.317%.

∴ The number of secondary open circuited volts required $= 110 + \frac{.317}{100} \times 110 = 110.35$ volts.

Consequently the number of volts per turn in the primary must be increased in the proportion of 110.35 to 110 and ∴ the number of primary turns must be decreased in the inverse ratio of 110.35 to 110.

$$\text{Or number of primary turns} = \frac{110 \times 2500}{110.35} = 2492.$$

So that we must wind the *H.T.* with 8 turns less. This will change the reactance slightly and a second calculation would give us a closer value. However this step is hardly necessary.

The transformer considered above when tested was found to give the required voltage under the stated conditions exactly.

Current Transformers.

In the case of very high currents it is customary to use what is known as a current or series transformer. This is sometimes used to insulate the line voltage from the meter service. This transformer consists of a few or perhaps one primary turn with a secondary winding of a number of turns depending on the ratio of transformation required.

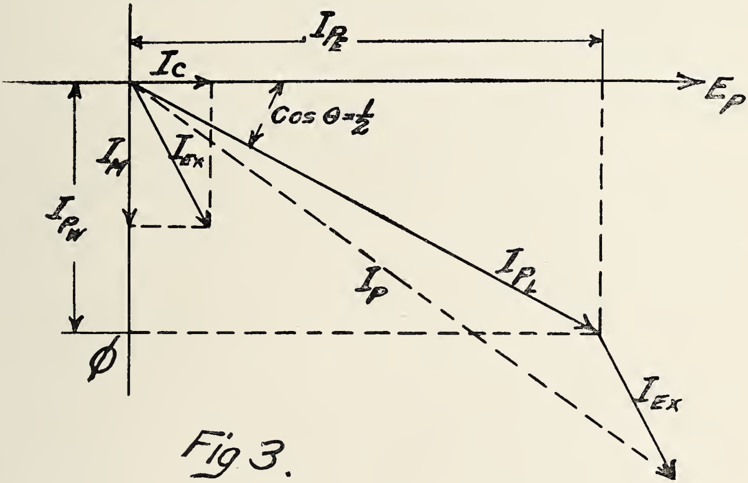


Fig 3.

In the ideal transformer the ampere turns primary are equal to the ampere turns secondary, but in the actual transformer this is not strictly true due to the core loss and magnetizing current.

It can be easily seen, since some of the current in the line, i.e. the primary current, is required for magentization and core losses that the actual volts per turn will be less than would be the case if the whole primary current were effective in producting induction. For this reason the number of turns in the secondary should be correspondingly decreased as follows:—

Let T_p, T_s, I_p, I_s be the primary and secondary turns and amperes respectively.

Then $T_pI_p = T_sI_s$ (For the ideal transformer).

Suppose I_m = magnetizing current.
I_c = Current supplying the core loss.

The actual current in the primary which induces a voltage in the secondary is then the vector difference between I_p, I_m and I_c $= I_r$.

The value of I_r can be found from vectors as shown in Fig. 4.

The construction involves a 100% *P.F.* but will apply for any power factor.

Insert then this value in the equation for the ideal transformer. expressed vectorially.

$$I_r = I_p - I_c - jI_m$$

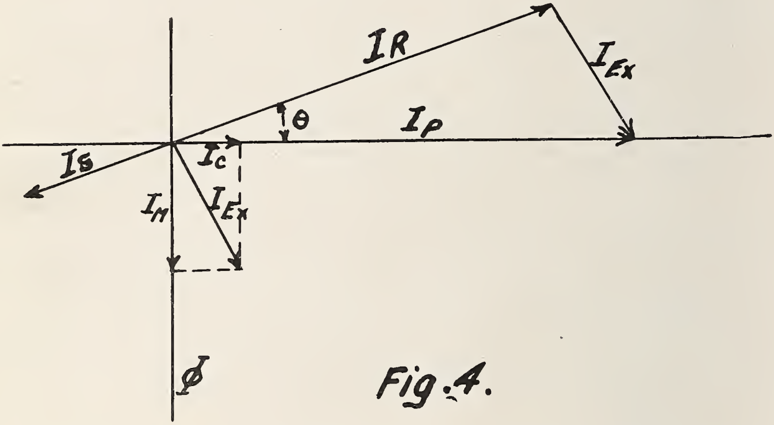


Fig. 4.

jI_m indicating a vector of value I_m in quadrature with I_p or I_c.

Formula for transformer now becomes:

$$T_p I_r = T_s I_s.$$

$$\therefore T_s = \frac{T_p}{I_s} (I_p - I_c - jI_m)$$

If $T_p = 1$, as in the case of a great many current transformers,

$$\text{Then } T_s = \frac{I_p - I_c - jI_m}{I_s}$$

I_c is determined from the design knowing the dimensions of the iron circuit, voltage which transformer is required to generate as a choke coil and data on iron used.

I_m is found from data on iron and iron circuit. Since the compensation in the case of a current transformer is expressed in ampere turns, then the formula becomes

$$T_s I_s = T_p (I_p - I_c - jI_m)$$

For ordinary commercial transformers this value of ampere turns compensation is 20 where the transformer is designed for 800 ampere turns.

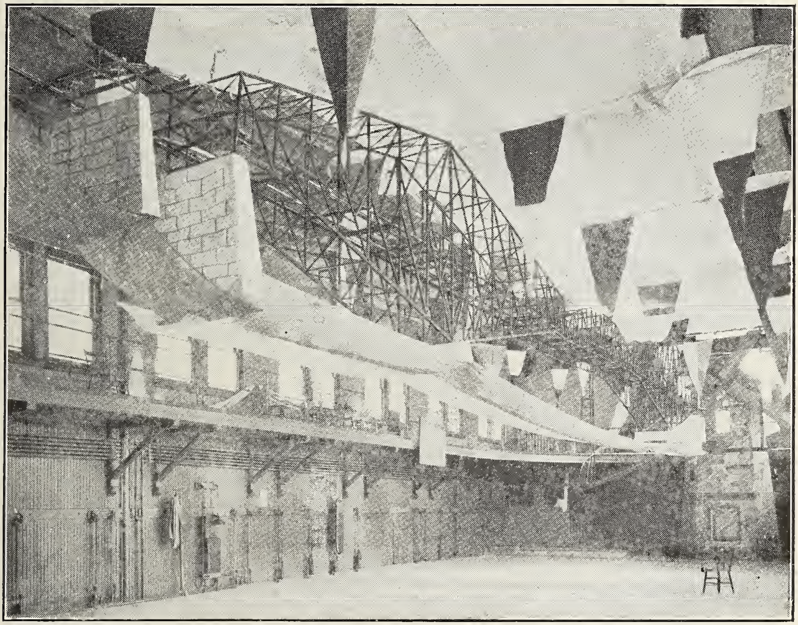
By a glance at Fig. 4 it can be seen that θ is approximately the phase displacement of the current transformer. On light load operation, say 15%, this phase displacement might run as high as

10°, which in the operation of a wattmeter might cause a considerable error. Under full load conditions the same transformer had about 3° displacement.

It is, therefore, apparent for accurate meter readings, when use is made of instrument transformers, that proper compensation is absolutely essential.

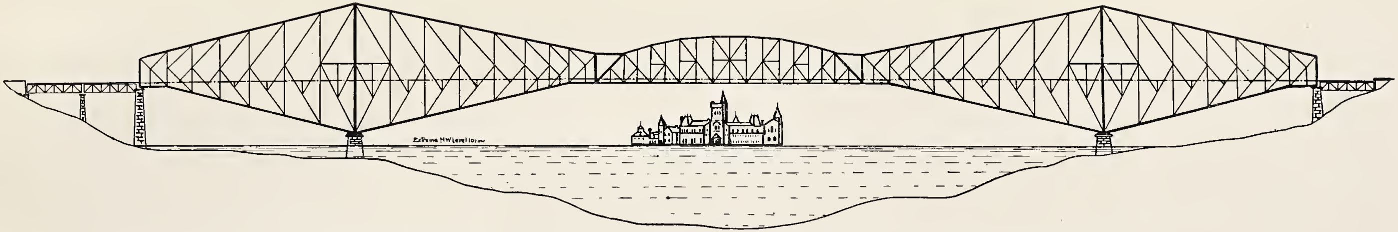
THE SCIENCE DANCE AND ITS ENGINEERING FEATURES

On Friday evening, Feb. 9th, the coldest night in seventeen years, the Engineering Society held its second annual At-Home, in the University Gymnasium, and, for several reasons, it is one that will be remembered.

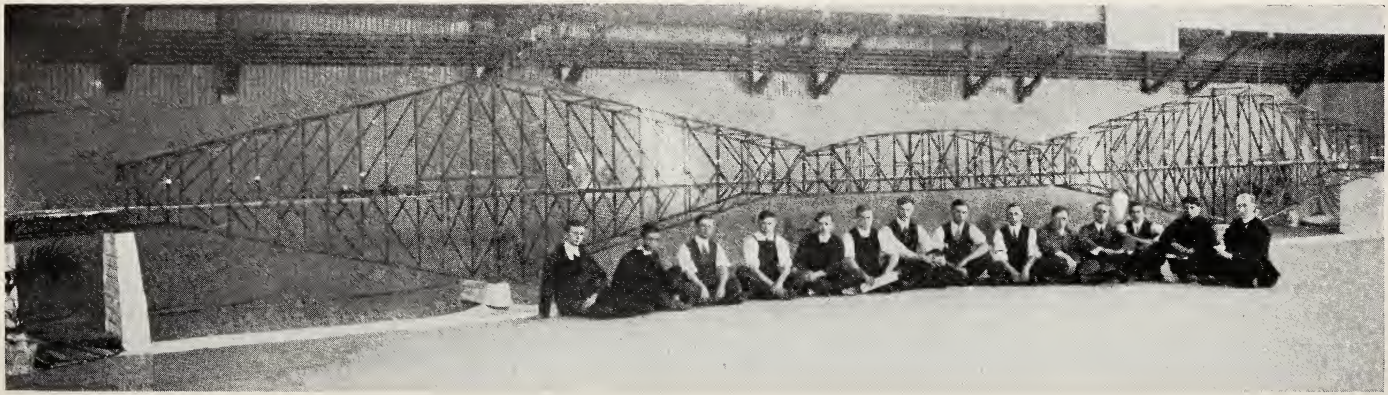


The Science Dance—View of the " Bridge " after the Removal of Wall Decorations

Historically, it is the last of all the brilliant social functions to be held in the old gymnasium, and in brilliancy it outshone all its predecessors. The floor was good, the music excellent, and the decorations all that could be desired. The walls and ceilings were completely covered with yellow, blue and white bunting, and a very successful system of indirect lighting installed, the light being furnished by forty 100 watt Tungsten lamps, which were concealed in ten inverted domes hanging from the ceiling. The light was thrown upwards against circular reflec-



Relative Sizes of the Quebec Bridge and Main Building, Universily of Toronto.



The Bridge Reproduction, and the Staff of Engineers who are Responsible for the Work.

tors six feet in diameter, which in turn reflected and diffused the light in such a manner as to give a most pleasing effect.

An attractive feature at the east end of the gymnasium was a model of a Dutch windmill. The credit for its striking appearance is due to the artistic taste of the fourth year students in architecture, and for its mechanical perfection to the untiring efforts of their colleagues in the mechanical and electrical departments. The tower of the windmill was about twenty feet in height, and the sails in proportion. The motive power was furnished by a one-eighth horse-power electric motor from the electrical laboratory. The feat of reducing the speed from that of the motor to that of the sails was accomplished by the use of a carriage wheel as a belt pulley. The only thing lacking in the installation was grease, the mixture of soap and oil used for lubricating purposes proving unequal to the occasion, resulting in the realistic squeak. At one time the creaking of the wooden shaft so rivalled the orchestra in the volume of sound produced that the musicians threatened to suspend operations if the mill did not cease its competition.

The most novel and striking feature of the decorations was a model, one-fiftieth size, of the new Quebec Bridge, which is being built by the St. Lawrence Bridge Co. The model measured over all about sixty-five feet in length, six feet in height, and two feet in width. It was suspended from the ceiling by sixteen wires one-sixteenth of an inch in diameter. On the floor of the bridge a double track railroad was laid, on which a miniature train was operated by means of electricity, the controlling switches being placed in the gallery. As the rails were not securely fastened to the ties the train service was brought to an untimely end by the locomotive eventually trying to crawl down between the rails to enjoy the revelry on the floor below. Rows of six candle power electric lights were placed along each truss, and bunting was draped about the bridge and piers to represent the water and banks of the river.

The structural parts of the model were designed and constructed by the fourth year students in Civil Engineering, with some assistance from students of the other years. The railroad and lights were installed by the mechanical and electrical students. In the structure were used about seven hundred feet run of clear pine one-half inch square, about the same amount three-quarters of an inch square, and about one hundred and fifty feet one inch square, with annealed iron wire, nails, tacks, and black tape, ad infinitum, not to mention the paper and cardboard in the piers. The bridge received one coat of black paint consisting of lamp black mixed with water and a small quantity of glue.

The work of construction consumed all the students' spare time for about two weeks, and probably some time that was not spare.

A description of the dance would not be complete without mention of the supper, which was served in quite an unusual manner. After the ninth dance, a sufficient number of tables were run in upon the floor of the gymnasium to accommodate all the guests, who sat down in quartettes to a very substantial repast.

The following patronesses were present and received the guests: Mrs. Falconer, Mrs. Galbraith, Mrs. C. H. C. Wright, Mrs. Haultain, and Mrs. A. T. Laing.

The accompanying sketch is shown in order to give a comparison of the size of the Quebec Bridge, when finished, with that of the main building of the University, both being reproduced to the same scale. The other photos give an idea of the appearance of the structure as reproduced by the Science men.

A. C. Spencer, B.A.Sc., '07, for two years with the McClary Company, London, has associated with the Hamilton Stove and Heater Co., as their mechanical engineer.

The following are among the graduates in electrical and mechanical engineering employed by the Canadian General Electric Company, at the Peterborough shops: W. H. Philip, '09; J. J. O'Hearn, '09; T. E. Freeman, '09; H. J. McTavish, '10; A. L. Sutherland, '10; H. K. Wyman, '11; T. J. Farrelly, '10.

Professor L. B. Stewart was elected president of the Royal Astronomical Society of Canada at the recent annual meeting of the society.

Mr. E. L. Cousins, B.A.Sc., '06, has been appointed to the position of engineer to the Harbor Commission of Toronto. Mr. Cousins has recently been assistant engineer, having had charge of the railway department and of bridges and docks.

We regret to announce the death at his home in Nortonville, Ont., of W. T. S. Ruston, who succumbed to pneumonia on January 17th. He was a member of the second year.

The Canadian Forestry Association met in Ottawa on Feb. 7th and 8th. Forest conservation was a problem receiving a great deal of consideration and discussion. The evening session of the first day was in the form of a banquet, in which the Canadian Lumbermen's Association joined, this body having held their annual convention on the 6th inst.

Mr. A. J. Latornell, '03, city engineer for Edmonton, has resigned to accept a similar position elsewhere.

Professor Angus gave an illustrated lecture to the Canadian Mining Institute at their regular meeting on January 13th. The subject was "Types of Steam Engines," including rotary and reciprocating types.

Willis Maclachlan, '06, is local manager at Belleville of the Trenton Electric and Water Co., and district superintendent of the Seymour Power and Electric Co.

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THE PLACE OF MOTION STUDY IN SCIENTIFIC MANAGEMENT*

By Frank B. Gilbreth, M.Am.Soc. M.E.

Mr. Chairman and Gentlemen:—

The subject of my paper is "The Place of Motion Study in Scientific Management." You undoubtedly realize that this is but a very small portion of Scientific Management, but, during the time that is alloted me for this paper, it will be impossible for me to give you anything more than a meagre description of this part of Scientific Management, with its relation to the other parts.

This I can best do by showing you graphically two plans of management. The first of these represents what is variously known as military or traditional management. As you will note here, each man is responsible to one man only above him, and is in charge of all below him. Thus, it is the custom for any man to come in contact with one man above him only, the line of authority being single and direct. Traditional management has been used for centuries in military organizations, and has also been used many times in religious organizations and political organizations. The division is by men, by grades of men rather than by functions.

The second chart represents functional or scientific management, or what would be called, but for objections by Dr. Taylor, the Taylor system of management. Here the division is by functions. The first functional division is the separation of the planning from the performing. Graphically, this separation is represented by the horizontal line. All functions above this line are of the planning, all functions below this line are of the performing. Note the functions shown on this chart, namely, four functions in the planning and four functions in the performing. Note also their relation to each other, and to the individual worker.

This chart shows one such worker represented by the lowest circle. There could be no objection to representing each individual worker by such a circle, but the relation of each such worker to those over him is exactly the same. Hence, the lowest circle is typical.

It will be noted that the worker receives orders directly from eight different foremen. You will, perhaps, suggest, on observing this, that it has often been said that no man can serve two masters.

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*Read before the University of Toronto Engineering Society, Friday, March 8th, 1912.

This holds good to-day, even in Scientific Management. But under Scientific Management the worker does not "serve eight masters" nor eight functional foremen, but, on the other hand, he receives help from eight different foremen or teachers. In this way, his case is not very different from that of the student who receives instruction from eight different professors, in eight different studies.

The four functions in the **planning** department are represented by

(1) Route Clerk and Order of Work Clerk
(2) Instruction Card Clerk
(3) Time and Cost Clerk
(4) Disciplinarian.

While I speak of each function as being represented by one person, as a matter of fact each function may include any number of individuals, according to the kind of work, and the number necessary so to perform that function as to eliminate all possible waste. Each one of these four men of the four functions in the planning department, is supreme in his respective function. All deal directly with the worker, and all deal directly with the four functional foremen who are in the performing department.

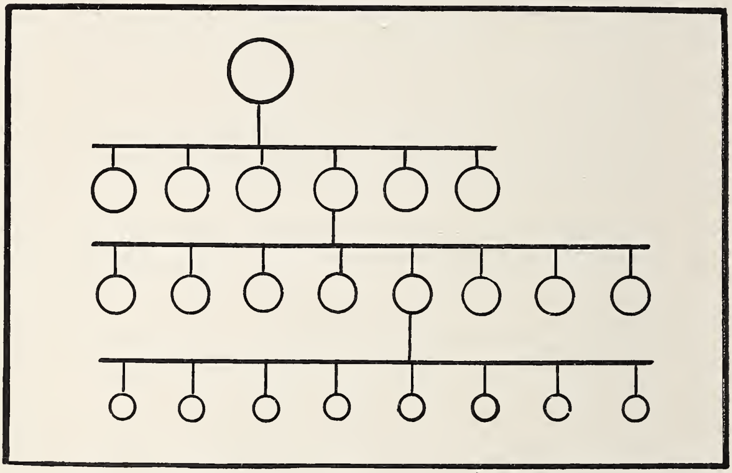

FIG. 1—Diagram illustrating the principle of Traditional or Military Management.

Of the **performing** department we have four functions represented by

(5) Gang Boss
(6) Speed Boss
(7) Repair Boss
(8) Inspector.

These functions, like those of the planning department, are represented by as many men as the nature and amount of work justifies. All such representatives deal, as the chart indicates, directly both

The diagram on page 179 is incorrect. The proper figure is shown below.

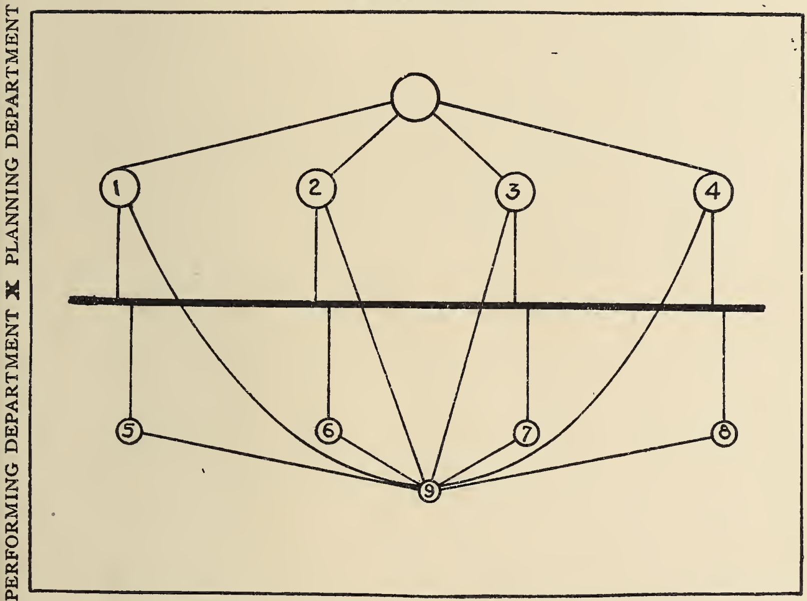

FIG. 2—Diagram illustrating the principle of Functional or Scientific Management.

with all individuals in the planning department. and with each individual worker.

I will now explain to you, briefly, the duties of the man handling each function, and at the same time call your attention to the subject of this paper, "Motion Study," which is a very small portion of the work of function No. 2 in the planning department under the instruction card clerk, and to the relation of this Motion Study to the other parts of Scientific Management, as shown in the chart.

Route Clerk

The duty of the route clerk is to plan in advance the path of each piece of material, worked and unworked, as it passes through the shop or as it is handled by each and every member of the organization who has anything to do with it. He is to decide the three dimensions of the path, and the route that the material is to pass through, whether it is to go to the stores or into temporary storage piles, or directly through the shop as fast as it can be moved. His function is not simply to look after the details of the moving, but broadly, to determine the entire transportation career of the material. For example, in building operations, he would determine where the car was to be placed to be unloaded, where the material was to be unloaded, when it was to be moved into the building, and exactly what path it would follow across the floor, up the aeolevtrs, and to its final resting place.

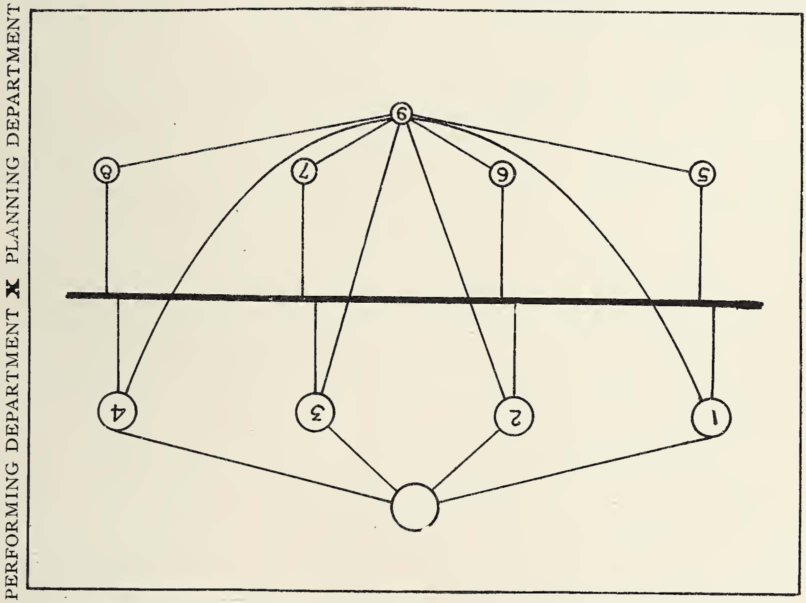

FIG. 2—Diagram illustrating the principle of Functional or Scientific Management.

Often the route clerk is able to greatly simplify the path of the materials, especially on large orders, by a rearrangement or routing of the machinery. I have had one case in my experience where it was cheaper, in a woodworking shop, to have the machinery placed on heavy pieces not attached to the floor, each operated by an individual motor, and to move it around into as nearly a straight line as possible, in order to accommodate the peculiarities of sequence of events of each particular order, when such order was large enough to warrant moving the machinery. The route clerk's duties, also, oftentimes consist of demanding a new path, that is, ordering that machinery not used be removed, so that he can route his material by a more economical method. After he has determined the exact path by which the material shall be routed, he embodies his conclusions in route charts and route sheets; these illustrate his orders graphically, and are worked out in detail by the instruction card department.

The Instruction Card Clerk

It must not be supposed that the instruction card function consists wholly of the work of actually writing out the instruction cards. This is the name of the function in general, and this function may be handled by several men of different capacity in the instruction card function, that is to say, the department may be divided into subfunctions. It is the duty of this function to work out in detail, that is to say to devise and construct, an instruction card for each element of the route sheets and route charts. The instruction card department must furnish in the greatest detail possible, such directions as will show two different classes of men their duties, namely—

(a) The worker, who must know how to perform the particular work shown on the instruction card,

(b) The functional foremen in the performing department, who must know exactly what he is to see that the worker does perform, and exactly what he is to teach the worker in order that he may so perform his work as to conform to the instruction card and to satisfy the man who made out the card.

The Time and Cost Clerk

After the worker has performed his work, a return of the time that it took him to do his work, together with its cost, goes to the time and cost clerk, who figures out the payroll, the bonuses, and the cost of performing each task.

The Disciplinarian

He is the man who handles all matters in the entire organization pertaining to disciplining. He must be a broad gauge man who is able to keep peace in the organization; to anticipate and prevent many disagreements and misunderstandings before they actually occur, and to arbitrate or judge fairly such disagreements as actually take place.

Now of the functions in the performing department:—

The Gang Boss

No. 5 is that of the gang boss. There may be many gang bosses in this department, in fact there are frequently five gang bosses of one trade. In such case, there would be an over-gang-boss in charge. There may be gang bosses in this function of twenty or thirty different trades, in fact of as many trades as are at work, or, possibly, one gang boss might look after two or more trades, or, on the other hand, there may be five gang bosses for one trade. The gang boss is not the "strong arm" type of man represented by the mate of the vessel of former days, who boasted that he could lick any man in the entire crew, and often did so for no other cause than to prove his words. He is now a man who can teach the worker the methods shown on the instruction card. His duty is to see that the worker performs the work required exactly as called for, and of the prescribed quality shown on the instruction card. In order to get his best work, and to enlist his zeal, it is usually necessary to pay him a bonus for each and every man under him who in turn earns his bonus, and a double bonus if every man in his gang earns the bonus. For example, suppose the gang boss received $3.00 per day, and had twenty men working under him, he would be paid, say, in round numbers, approximately 10 cents apiece for each man under him who received his bonus; and, if all twenty of the men received their bonus, he would receive a double bonus of 20 cents apiece for the entire gang.

You can readily see how such a plan of management as this will bring out co-operation as would no other plan, and I want to state here emphatically that there is nothing that can bring about results from Scientific Management, and the economies that it is possible to effect by it, except the hearty co-operation of the men. Without it, you have no Scientific Management.

Speed Boss

The speed boss, No. 6, regardless of the popular impression as to his duties, does not speed up the men, in fact he has very little to do with speeding the men. His duty is to see that the machinery moves at the exact speed called for on the instruction card. You can readily see that there is some one speed that is more desirable than any other speed; for example, the speed of a buzz planer or a circular saw is very dangerous when it is too slow, while on the other hand, the speed of a fly-wheel of an engine is very dangerous when it is too fast. The one that is the most desirable and safe is the speed that the instruction card man attempts to set on the instruction card, and it is the duty of the speed boss to see that the machinery runs at all times at exactly the prescribed speed. He not only shows the worker how he can make his machine run at the speed called for, but, if there is a question as to its being possible to run at this speed, he must be prepared to teach the worker by doing the work himself, or provide a man who can comply with the equirements of the instruction card.

Repair Boss

The next function is that of the repair boss. His duties consist principally of carrying out repairs and overhaulings, such as are called for on instruction cards that are given to him at regular, predetermined intervals. In this way breakdowns, as far as possible, are avoided. The repair boss, however, must be a resourceful man, prepared, in case of emergency, to jump in and repair any such breakdowns as may occur, even in the absence of precise directions or an instruction card.

Inspector

The eighth function is that of the inspector. His work is decidedly different from that of the inspector under the old type of management; for example, his inspection must result in constructive criticism, not destructive criticism. It is his duty to see that the material is rescued when it is not handled, or worked, exactly as called for on the instruction card.

Many times, under traditional management, the inspector comes around after the work is done, condemns it, and walks away, leaving it to others to see that the work is taken down, and, perhaps, carted from the premises. Under Scientific Management the inspector is required to stand near the worker when he is handling a new piece of work for the first time, in order to see that he thoroughly understands his work as it progresses. Thus the material is not spoiled. If the worker has a task of, say, fifty pieces, the inspector inspects the first piece most carefully, to make sure that he is satisfied that the worker knows exactly what he is to do, how he is to do it, and the quality prescribed by the instruction card.

The Workman

As for the individual worker, it will be seen that he receives not only an instruction card telling him what he is to do, how he is to do it, how fast he is expected to do it, the prescribed quality with which the work must be done, and how much pay over and above his usual day's wages he will surely get if he does all that is called for on his instruction card, but also, he receives personal teaching. The gang boss acts as his teacher constantly; the speed boss he can call on at all times to assist him with the speed; the repair boss co-operates with him to see that his machine is constantly kept in such repair that he can earn his bonus, and the inspector will also teach him at any time, and show him wherein he is making a deviation from the quality called for. Moreover, the functional foremen in the planning department are ready, at call, to explain their instructions. Thus he has every help that is possible, to enable him to earn the exceptionally high wages that are offered for Scientific Management. He is assured of the "square deal" from the foremen who are over him, and he always has the same opportunity to appeal to the disciplinarian, in case he is not being well treated, that a foreman would have in case the worker was not doing his work as well as he could do it, or was not trying to co-operate with the other workers.

Having shown the principal functions of Scientific Management and their relation to each other and to the individual worker, we are now ready to concentrate on Motion Study.

The three most oblivious economies to be obtained by Motion Study would be to use (1) the fewest motions, (2) the shortest motions, and (3) the least fatiguing motions; but these, however, are but a small part of the list of savings that could be obtained.

For example, in one organization with which I have recently been working, I found a man who had been working in the same shop for over twenty years whose duties consisted of doing work that required his hands to be within six inches of the floor on which he stood, practically all day, except when he was resting. This man was one of the tallest men that I ever saw, he surely was more than 6 feet 6 ins. On the other hand, I found in the storage department one of the shortest men I ever saw, who was piling cases up in a pile about 7 feet high. Now it must readily be seen that there are other things to be considered, as for example, the selection of the men that they may make, naturally, the best adapted motions for the work.

Motion Study is a part of the function No. 2 of the planning department. It is here necessary to go back a little way and see what it is that the instruction card man is supposed to do. His duty first of all is to devise a way that is the most economical and the least wasteful of any way that can be devised, and the nearer that he can get to perfection the better he is in his function. The nearer he devises a method that is fundamentally right the more scientifically can rates be set. It must be remembered that under Scientific Management the rate is never cut. Any manager who is familiar with the evil by-products of cutting the rate on piece work will readily understand the tremendous benefits that accrue from any system where the rates are so fixed that not only the rate need never be cut, but that there is no incentive to ever cut the rate. Cutting the rate results in scientific loafing, which is quite the opposite of hearty co-operation, and, as I have said before, without hearty co-operation you cannot have the great savings that make it possible to pay the unusually high wages to the workmen, and at the same time provide the unusually low production costs to the employer.

Motion Study is so intimately related to time study that it is quite difficult to specify exactly where one begins and the other leaves off. Perhaps the best way to describe it would be to say that Motion Study is for the purpose of seeing that the process is right, and time study is for the purpose of determining how long each element of the process will take, and how much time must be devoted to rest for overcoming fatigue.

Motion Study theoretically is supposed to furnish measurable units for time study, but the units are so small that they have not, until recently, been timeable.

I expect to place a mechanical device on the market within the next two months that will time accurately the motions of the workmen down to the thousandth of a minute without any of the inaccuracy that comes from the human element in the observing. For twenty-five years I have been advocating the method of teaching right motions first instead of teaching quality of output first. You undoubtedly will realize that it takes considerable courage (or else positive proof) to advocate openly neglecting all thought of the quality temporarily for the sake of great precision of right motions.

Only a short time ago I told two prominent members of the A.S.M.E. that I had had unusual success with teaching boys and men new methods by using great care in having them use the right motions first and then the right motions with increasing speed until the maximum speed was reached and to give no thought whatever, meantime, to the quality. The answer of these two gentlemen was —that if that was the way that I did my work I couldn't expect ever to do any work with them.

Now it is quite difficult, if not actually impossible, to make some people realize that great precision of motions is identical to giving great attention to quality of output, for if the motions have sufficient precision the quality will undoubtedly have also the greatest precision that would be obtainable by that particular workman. I think that one reason that the great benefits that can be derived from emphasizing teaching the right motions first, was not recognized, was because the teachers of the trades did not know what the right motions were. Ordinary photographs, stereoscopic photographs and motion picture photographs now enable us to recognize and determine, separate and measure the various motions with great accuracy, and the results are quicker teaching, automaticity of motions, habits of right motions and less fatigue and less percentages of fatigue. These all permit much faster motions.

There are a great many other reasons why motions should be standardized, and if they are standardized, it goes without saying that the motions should be the right motions. One of the reasons for taking great care in standardizing motions is that it reduces enormously the amount of time study that must be taken, and time-study is at best an expensive and somewhat tedious process. It is much more necessary that we have a standard method for each process early, than that we wait until we devise the best possible methods; however, it is, of course, desirable that the standard process shall be built up from the best known motions at the time that it is standardized.

Now there are a great many variables that affect the motions, and I give here variables as cited in the first edition of Motion Study. This is by no means a complete list as there are as many more variables recognized to-day, but this list will give you a fair idea of what we mean by the "variables that affect the motions," and oftentimes it will be found that the variables make necessary or advisable the complete elimination of certain motions that were considered necessary before due consideration was given to the variables. These variables may be preferably divided into three kinds; (1) the variables of the worker; (2) the variables of the tools, equipment, appliances; and (3) the variables of the motion itself.

Variables of the Worker

Anatomy, brawn, contentment, creed, earning power, experience, fatigue, habits, health, mode of living, nutrition, size, skill, temperament, training.

Variables of the Motion

Acceleration, automaticity, combination with other motions and sequence, cost, direction, effectiveness, foot-pounds of work accomplished, length, necessity, path, play for position, speed.

Variables of the Surrounding Equipment and Tools

Appliances, clothes, colors, entertainment, music, reading, heating, cooling, ventilation, lighting, quality of material, reward and punishment, size of unit moved, special fatigue-eliminating devices, surroundings, tools, union rules, weight of unit moved.

The scheme of Motion Study is to discover perfection and to perpetuate it automatically.

Scientific Management has been extremely slow in making an advance in the industries and the principal reason for this is that the scientific managers have been obliged to train their own men. There is no school at the present time that has sent out young men who were even familiar with the vocabulary of Scientific Management, so far as I and my associates have been able to determine.

After having determined the right motions, the right times for the motions, and having grouped them into cycles of elements, of subdivisions, of processes, we then determine the amount of rest that must be allowed for overcoming fatigue, and then we have the standard task for the standard man, and here I must tell you about the difference between the "standard man," the "first-class man" and the "given man." The motions and the time of motions are taken on the standard man; that is, the best man procurable, the best man that we can get to be observed.

While motions and the time of motions have been determined by observing the best men procurable, it is not to be expected that other men will be obtained who will be as good as the best man picked out for this purpose. The first-class man is the man who is best adapted to this particular work; that is to say, the best man adapted to do this work continually and thrive. The first-class men are obtained from the given men. Some find that they cannot do the work, and either become discouraged or assigned to other work before they get discouraged. Many people think that the hard task makes an unwarrantable hardship upon the worker, but this is not so, for Scientific Management contemplates having each man work at the highest class of work for which he is mentally and physically and by experience able to work at continuously and thrive. The interdependence of all the men from the individual workman to the highest man in the planning department is so noticeable that it is necessary that those men only are picked out to do the work who are capable of doing it so as not to delay those that follow him in a dependent sequence of operation. If an inefficient man who could not be depended upon to do a certain predetermined piece of work were permitted to work at a place where he failed to perform his task day after day, he would interfere with all those men who followed him earning unusually high wages; therefore it would not be fair to the other men to permit any man to work at any job that he was not fitted to do continuously to the quantity called for in the task.

Now that there is so much literature on the subject of Scientific Management why is it a fact that the progress of Scientific Management has been so remarkably slow? The answer to that question is that many people who are thoroughly familiar with the duties of the men and the various functions are not familiar with the pitfalls that are ever present in its installation. As I have said twice before, the entire scheme is dependent upon the hearty co-operation of everybody in the organization, and workmen everywhere have been deceived so many times in the past that they are naturally suspicious that this Scientific Management is nothing more nor less than a new fraudulent confidence game presented to them in a more deceptive form than they have ever seen, and they believe that it is for their best interests to smother while it is still young.

On the other hand, there never has been a case where Scientific Management has been put in properly that all the workmen did not realize that it was much better for them than any form of management that they had ever seen. To those of you who are interested in Scientific Management I respectfully suggest that it would pay you to go to Philadelphia and to see the Tabor Mfg. Co., and the Link Belt Co., who have had the Taylor System longer than any other concern in the country.

Now that there has been many successful demonstrations of Scientific Management where the workers receive much higher wages than ever before and where the costs of production are lower than ever experienced by manufacturers before, it seems extremely unfortunate that the terrible wastes that are going on where Scientific Management is not in operation, should continue, and I therefore hope that this university will consider seriously the study of Scientific Management not only for the education of the young men who are going out in the world as engineers, but also with the idea of establishing a permanent station for the collection of Motion Study and time study data working in co-operation with similar colleges in the United States and Canada and also with various organizations who are doing good work toward investigating and disseminating information regarding Scientific Management, particularly the Society to Promote the Science of Management.

The problem is too great for any one firm, corporation, or college; in fact, this is work in which all English speaking nations should unite the same as we have already done in our investigations of matters pertaining to medicine, agriculture, and the animal industries.

I hope to see an international bureau for the study, for the collection, study cataloguing and dissemination of data relating to Scientific Management that the workmen of all countries may be benefited and that unnecessary wastes may be eliminated.

I fully appreciate the honor of having the opportunity to present this paper to you, for we recognize the University of Toronto as one of the foremost educational forces on the Western hemisphere.

MALLET LOCOMOTIVES FOR THE CANADIAN PACIFIC RAILWAY

By Frederick H. Moody, B.A. Sc.
Mechanical Editor, The Railway and Marine World, Toronto.

While this paper will centre on the recent construction of a series of Mallet articulated compound locomotives by the Canadian Pacific Railway, a little consideration of just what the Mallet compound is, where it originated, and what is being done towards its promotion in the United States and Canada, will first be essential to a fuller understanding of the conditions this newer and much mooted type of locomotive is being introduced to meet.

For those who are not familiar with the Mallet, it may be said that a Frenchman of that name was the first to design and successfully construct a jointed or articulated locomotive, a good example of such a type being shown in Figure 1. The word "articulated" is self-explanatory. The dictionary defines it, to "joint or to unit by a joint." Thus, a Mallet articulated locomotive is a jointed structure, independent units operating together in unison from a central control.

Mallet locomotives have been in more or less general use on the Continent for many years, the exact date being unknown to the writer. But the first one to be constructed in America was that built by the American Locomotive Co. to the order of the Baltimore & Ohio Railroad. Being of a radically different design from anything heretofore produced on this side of the water, it occasioned widespread comment, the general opinion being that it was "freakish" and that its maintenance would be excessive, if, in fact it could be operated at all. Such was not the case as the successful operation of that and numerous other locomotives of a similar type bear testimony. In fact, statistics gathered by the builders of that locomotive last year, showed that an aggregate of over 400 Mallets were in successful operation on 29 of the leading roads of America. This particular B. & O. locomotive showed a considerable saving, being able to replace two heavy consolidation locomotives that had previously been required to handle the same trains.

Figure 1 shows a heavy Mallet—one of a set of three—built in 1907 for the Erie Rd. by the American Locomotive Co at a time

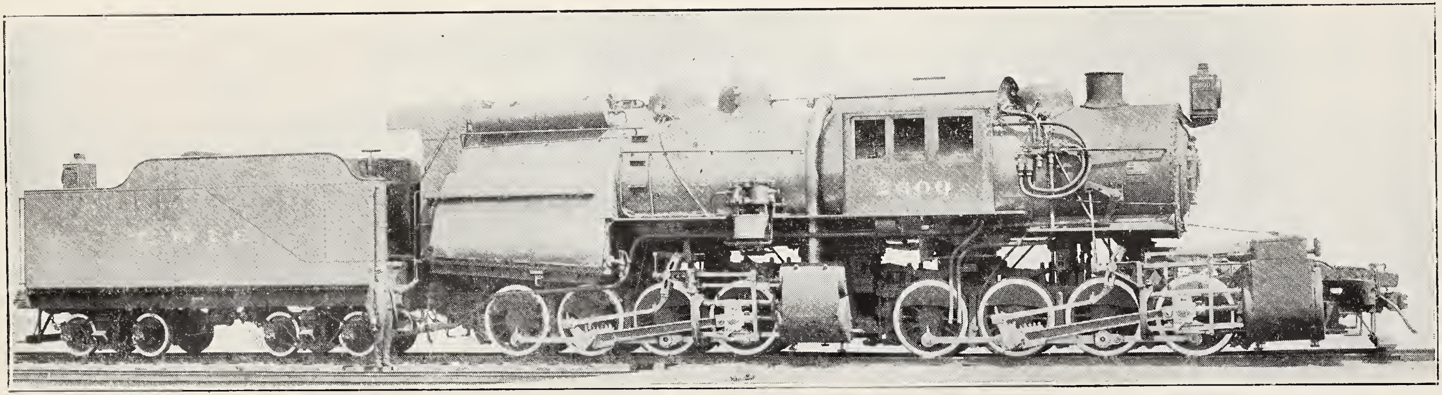

FIG. 1—An Early Mallet Locomotive for the Baltimore and Ohio Railroad.

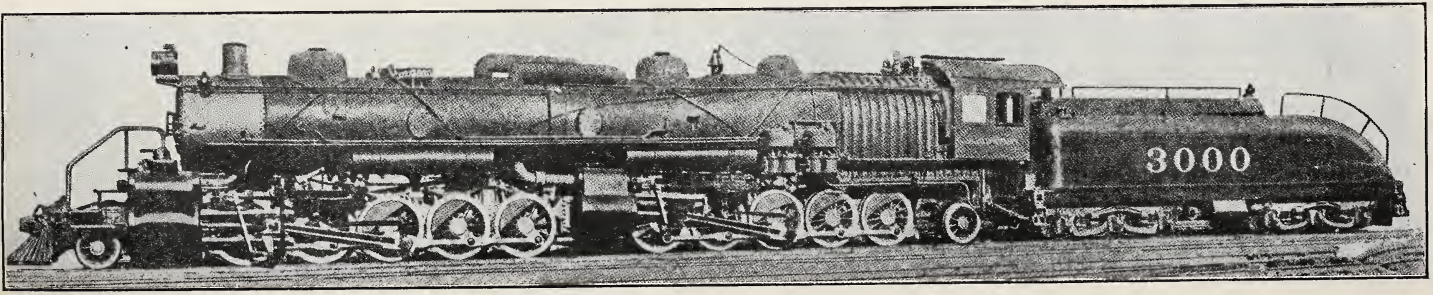

FIG. 3—Most Powerful Locomotive in the World.

when the writer happened to be connected with that firm. At that time, these locomotives were the heaviest in the world, the engine alone running up to a matter of 410,000 pounds, or 205 tons. As shall later be seen this record has since been greatly outdistanced.

Let us next consider the reasons for the introduction of such enormously powerful machines. Consider a medium-sized consolidation locomotive, working to its full capacity on a road with a ruling grade not exceeding say 0.5 per cent. This one locomotive would be perfectly capable of handling a given train under all the normal conditions to which it would be subjected on that division. But supposing, as in the case of a number of the United States trunk roads, some obstacle such as the Alleghany Mountains has to be surmounted; in this case there is a stretch of road varying in length from ten to fifty miles, with a heavy grade. This makes one of two things necessary; either the train must be broken up, into smaller units, or else be given assistance. The former may fairly be counted out, the cost and inconvenience being prohibitive, for a large part of the traffic is routed straight through from the West in solid trains; assistance is thus resorted to. On the roads cited, the grades at these heavy points are such as to require at least two locomotives similar in size to that handling the train up to that point, to act as pushers in assisting the train over the heavy grades and curves. This requires a double crew in the pusher service, increasing operating costs.

The question naturally arises—why not build larger locomotives of the same type, so as to require only one to act as pusher? The factor of limitations here enters. Were the locomotive to operate on a straight piece of track free from all curves, enlarging a rigid frame freight locomotive by lengthening it might be resorted to, but where curves are to be negotiated, a limitation is set to the length to which the wheel base may be increased. Likewise, the possibility of increasing the size upward and outward is held within bounds by the clearance gauge set by the engineering staff of the road, and by the fact that the axle loads must not exceed a certain figure —60,000 pounds, being considered an undesirable maximum. Consequently, any increase in locomotive size must be lengthwise, which, as just shown, is impossible with a rigid frame.

Hence, a flexible frame becomes necessary, resulting in the present universal adaptation of the Mallet where heavy freight-handling units are required. In fact, there are instances where they have been very successfully used in heavy passenger service.

As may be seen from the photograph, Figure 1, a Mallet locomotive really consists of two separate and distinct engine units under one steam-generating or boiler unit, the rear frame and boiler forming a rigid connection, with the front frame articulated or hinged, so to speak, to the rear one and free to swing from side to side under the forward part of the boiler when taking curves. This is shown to advantage in Figure 2, where a Mallet locomotive is shown standing on a curve, the front frame being shown swung over to one side. It can readily be seen that the whole locomotive thus becomes very flexible in operation.

There are other uses for the Mallet besides that of pusher service, increase in traffic over a given division by the increase in train size being probably the principal one. As a special instance of this, an installation of Mallets on the Pennsylvania division of the New York Central Lines may be cited. In this instance, 26 articulated engines replaced 60 consolidations, the overloaded single-track capacity of 1,000 cars every twenty-four hours being easily increased 40 per cent., making the capacity 1,400 cars per day. Those familiar with railroad conditions will realize what a tremendous volume of traffic this is for a single track road. A further saving is here obtained, the necessity of double-tracking the division being indefinitely postponed.

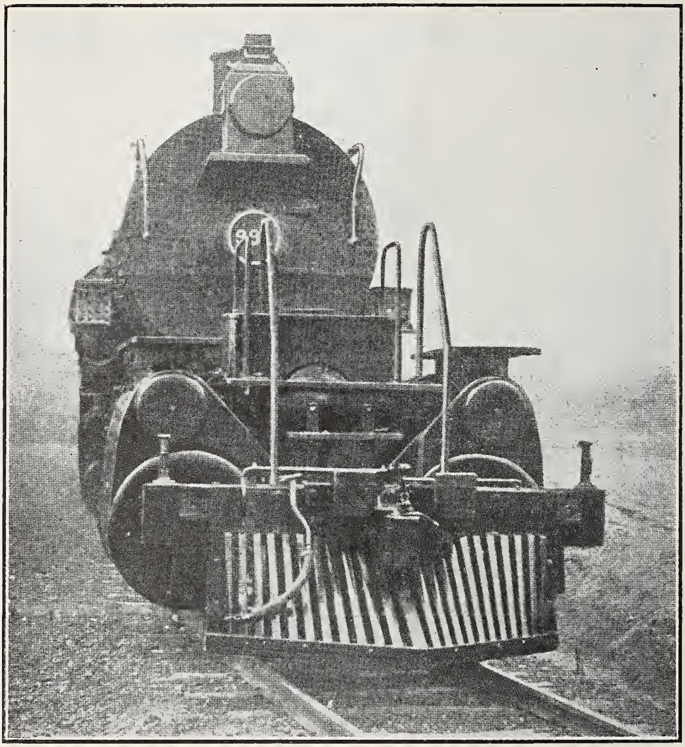

FIG. 2—Flexibility of a Mallet in taking a curve.

Before finally coming to the specific object of this paper—a description of new Mallets for the C.P.R.—another example of Mallet practice will be given. This example illustrated in Figure 3, constitutes the most powerful locomotive in the world, weighing as it does, 616,000 pounds—850,000 pounds including the tender. The wheel base of engine and tender is over 108 feet. This locomotive, constructed and put in operation by the Sante Fe last year,

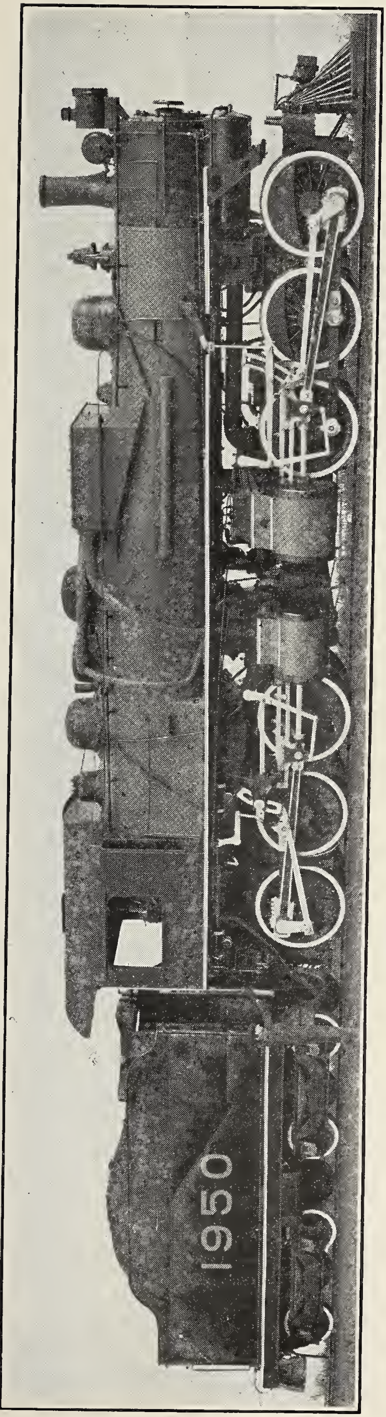

FIG. 4.—Experimental Mallet for the C.P.R.

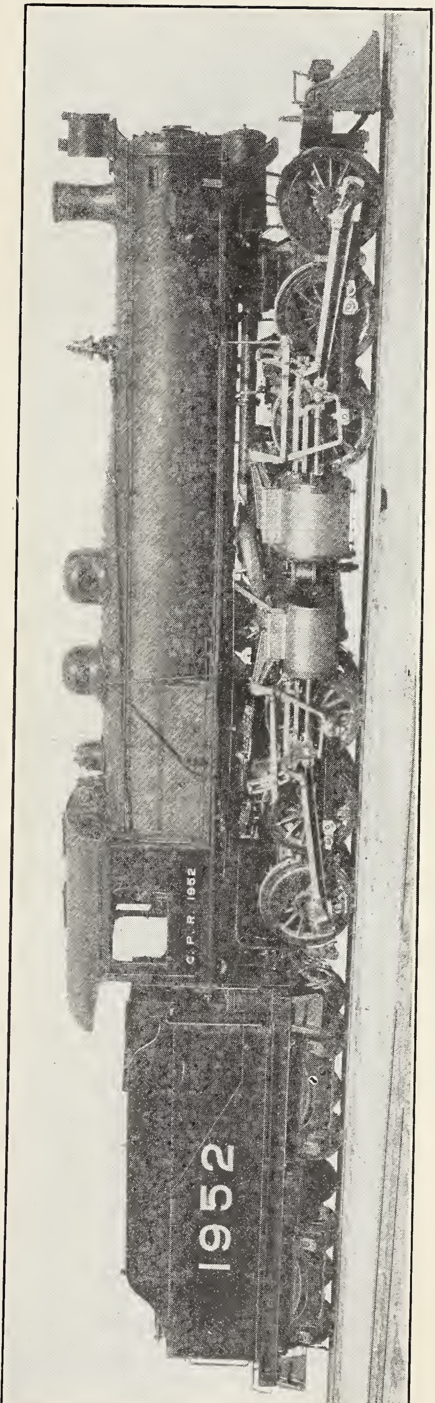

FIG. 8—C.P.R. Mallet designed on Basis of Tests on Experimental Mallet.

forms a marked contrast to the Erie locomotive mentioned earlier as being the largest locomotive extant at that time. This newer engine, constructed just four years later, marks an increase in size of more than 50 per cent. While it is scarcely safe to make any positive assertions, it would seem as if the limit had been reached, and that at least this locomotive would stand without peer for many years to come.

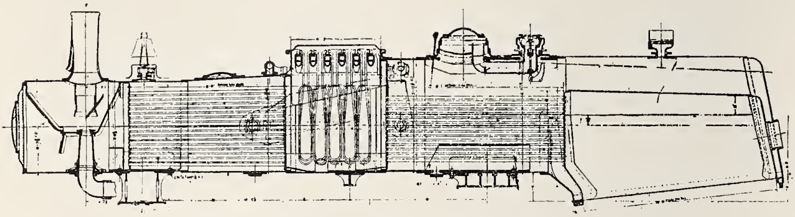

FIG. 5—Boiler of Experimental Mallet.

Coming nearer home, the activities of the Canadian Pacific Railway will next be considered. This very progressive road, always in the van in new motive power equipment, investigated the value of the Mallets by building an experimental one, Figure 4, to its own designs in its Angus shops. The object in mind was to produce a locomotive that could more economically handle freight traffic through the mountain sections of the British Columbia division where gradients up to 2.45, and 15-degree curves are to be nego-

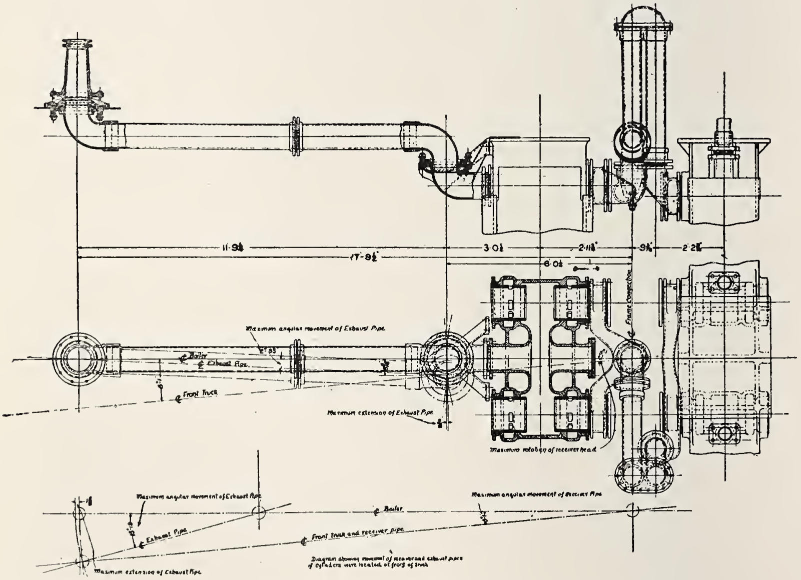
11·9¾
17·8½
3·0½
2·11⅛
9⅝
2·2⅞
6·0½
Frame Connection
Maximum angular movement of Exhaust Pipe
Boiler
Exhaust Pipe
Front Truck
Maximum extension of Exhaust Pipe
Maximum rotation of receiver head
Maximum angular movement of Exhaust Pipe
Maximum angular movement of Receiver Pipe
Boiler
Exhaust Pipe
Front truck and receiver pipe
Diagram showing movement of receiver and exhaust pipes if cylinders were located at front of truck
Maximum extension of Exhaust Pipe

FIG. 6—Steam Piping of Experimental Mallet.

tiated. The locomotives previously handling the traffic were 185,000 pound consolidations, capable of handling 424-ton trains. This Mallet was designed to handle trains up to 700 tons, and from tests to be mentioned later, the expectations were fully realized.

This locomotive was in the nature of an experiment, so in order to ascertain the correctness of certain theoretical premises held by the designers, some rather novel features of design were embodied in the construction. Principal among these were the boiler construction, and cylinder arrangement. Figure 5 shows this novel boiler. Instead of a plain tubular barrel section, the latter is divided into three sections—boiler proper, superheater compartment and feed-water heater. The water, first heated in the forward water-heating section, passes back through equalizer pipes to the steam-generating section, from whence the saturated steam passes to headers in the intermediate chamber, downwardly projecting superheater units bringing the saturated steam into contact with the hot flue gases. The superheated steam then passes on into the cylinders.

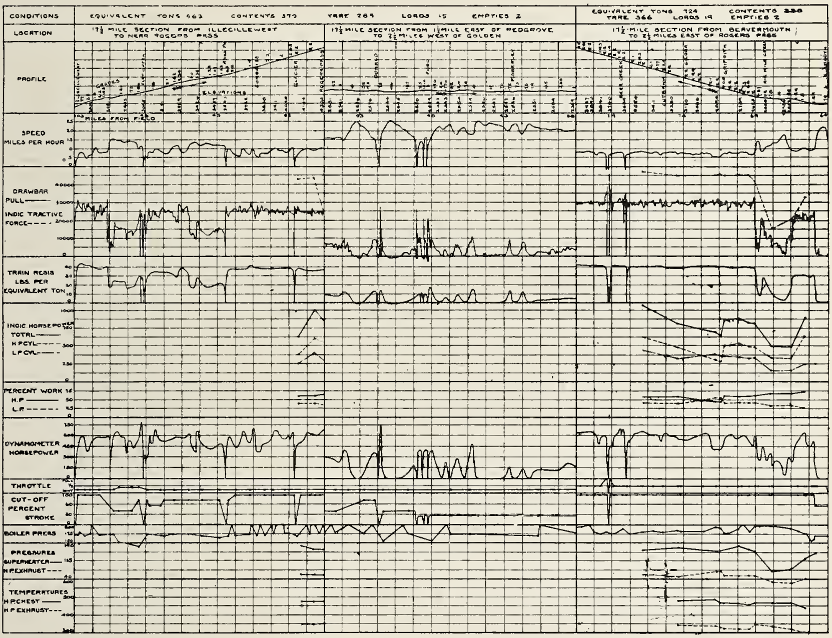

FIG. 7—Test Curves of Experimental Mallet.

Referring again to Figure 4, it will be noticed that the cylinder arrangement is different to that in common use on Mallets, forming a radical departure. Both pairs of cylinders, it will be noticed, are at the centre of the locomotive, head to head. The value of this arrangement can best be appreciated by reference to the piping diagram, Figure 6. The steam in the first place in exhausting from the high to the low pressure cylinders, passes across the intervening gap through a swivel pipe joint, to the moveable front engine cylinder. This swivel pipe joint is located directly over the pin connection between frame units. When piping the steam from the low pressure cylinders to the exhaust stack, provision must be made for allowing the exhaust pipe to lengthen as the front truck swings off centre, the angular displacement causing the distance between pipe centres to slightly increase. Now, had the cylinders been well forward, the relative movement of pipe centres would have been proportionally greater, making it necessary to introduce an exhaust pipe capable of meeting greater extensions, and to also have greater swiveling scope.

This locomotive was thoroughly tested out under both special and service conditions. The earlier special tests were made near the shops at Montreal where a gradient of 1.5 was to be had. These tests gave sufficient data to lead to a slight remodelling of the engine.

Following this, however, a very thorough series of tests under the service conditions for which the locomotive was designed, were conducted on the 130-mile stretch of mountain track from Field to Revelstoke, B.C. The more instructive of the results obtained are plotted in the curves shown in Figure 7.

All this experimental work gave the Canadian Pacific Railway mechanical department a great deal of data upon which to base the design of a further series of five Mallets, a description of which is embodied herewith. This new series, which has only recently been finally completed, consists of 4 compounds, 1951-4, and one simple 1955, all of the same general design. The general appearance of the compound Mallets of the series is shown in the accompanying illustration, Figure 8, while Figure 9 outlines the locomotive construction more in detail.

The following table gives the principal dimensions:

Type	0-6-6-0
Gauge	4 ft. 8½ ins.
Service	Pusher
Fuel	bituminous coal
Tractive power	57,000 lbs.
Weight, drivers	259,000 lbs.
Weight, total	259,000 lbs.
Wheel base, front engine	10 ft. 4 ins.
Wheel base, rear engine	10 ft. 4 ins.
Wheel base, total, engine	35 ft. 2 ins.
Wheel base, engine and tender	60 ft. 7 ins.
Weight on drivers ÷ tractive effort	4.54
Tract. effort × dia. drivers ÷ equiv. heat. surf	921
Equiv. heat. surf. × grate area	62
Weight on drivers ÷ equiv. heat. surf	72
Cylinders, h.p.	23 x 26 ins.
Cylinders, l.p.	34 x 26 ins.
Cylinders (simple engine 1955 only)	20 x 26 ins.
Valves. h.p.	11 in. piston
Valves. l.p.	12 in. piston
Driving wheels. dia.	58 ins.
Driving axles. main. 9½ x 12 ins.; others	9 x 12 ins.
Boiler	Radial stayed, wagon top
Pressure	200 lbs.
Firebox, size	120 x 69⅞ ins.
Firebox, sheets	5-16, ⅜, 1-12 and 7-16 ins.
Firebox, water spaces, sides, 4½ ins.; throat, 5 ins.; back, 3½ins.	
Tubes	154 2¼-in. dia.; 16 2-in. dia.; and 22 5¼-in. dia.
Tubes, length between sheets	20 ft. 1½ ins.
Heating surface, tubes	2,589 sq. ft.
Heating surface, firebox	180 sq. ft.

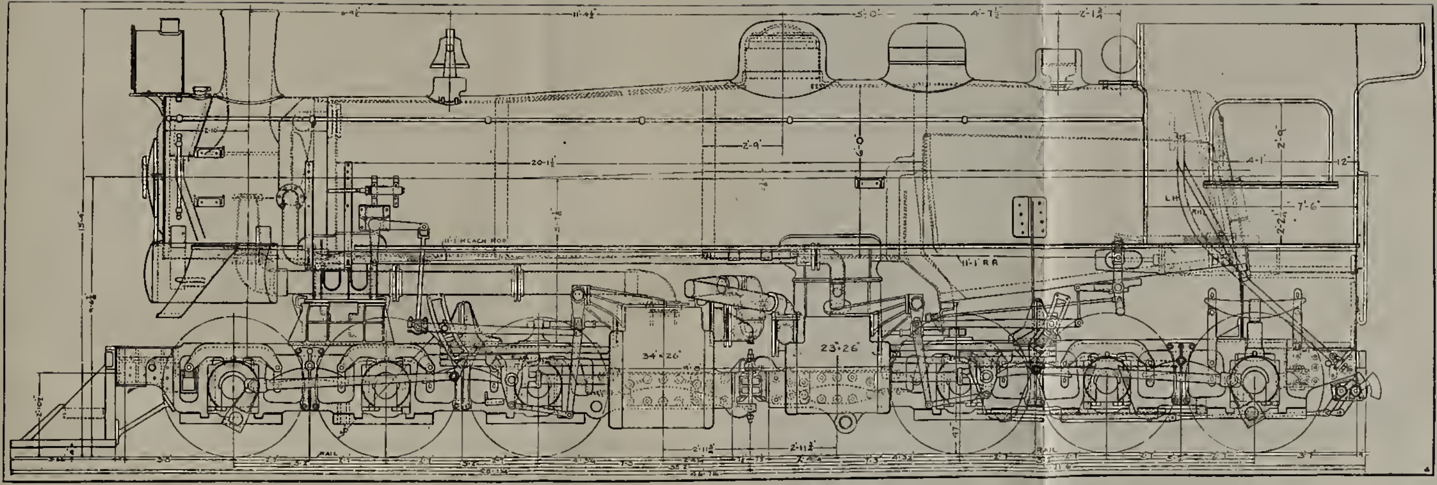

FIG. 9—Elevation of New Mallet.

Heating surface, total	2,769 sq. ft.
Superheating surface	548 sq. ft.
Equiv. heat. surf. (= total heat. surf. + super. surf. × 1.5)	3,591 sq. ft.
Grate area	58 sq. ft.
Tender tank, kind	semi-water bottom
Tender frame sills	centre, 13 ins.; sides, 10 ins.
Tender trucks, kind	equalizer
Tender wheels, dia.	34 ins.
Tender axles	5½ x 10 ins.
Water capacity	5,000 Imp. gals.
Coal	12 tons

A cursory inspection of both Figures 8 and 9 will show that the construction of these Mallet locomotives is decidedly different from the practice followed by United States roads that have added Mallets to their rolling stock. Principal among these points of difference are the arrangement of cylinders and the absence of leading and trailing wheels, placing all the weight on drivers and shortening the wheel base.

Boiler

The boiler used in this series of locomotives has been changed very materially from that used in the original experimental Mallet. In this newer design, a plain wagon-top, radially stayed boiler is used, this design being found preferable to the three-compartment type used experimentally.

The tube sheets, 20 feet 1½ inches apart, provide for flues of a normal length, in contradistinction to some recent United States designs, where tube lengths up to 24 feet are to be found. It is in every sense a plain barrel boiler of the extended wagon-top type, with the possible exception that the corners of the fire-box, both inside and outside, are greater than usual to increase the boiler rigidity, as lack of the latter is believed to be responsible for staybolt breakage in the end rows.

The feed-water heater and superheater chamber being eliminated, a superheater of the Vaughan-Horsey type is placed in the smoke-box, the arrangement of headers, etc., being noted in the elevation drawing, Figure 9. The injector check valve is located on the top centre line of the boiler, under the bell stand, and has three connections—one for the left and another for the right-hand injectors, and a third for connection with pipe or hose coupling for use in filling or blowing off the boiler.

Instead of placing both sand boxes on top of the boiler, as in the former design, one of them is located in the upper forward part of the smoke-box, feeders leading down on the inside of the smoke-box shell. The box is filled through a small door on the top.

The experimental locomotive had a double petticoat smoke stack. In the new design this has been eliminated and a single wide-flare stack introduced in its place.

Frame, Connections and Spring Rigging

The frames for each engine are one-piece steel castings, slabbed for the cylinder fit, and also for the front bumper and back foot-plate. The sections of both top and bottom rails of the frames are 4½ ins. wide by 4½ ins. deep and 4½ ins. wide by 3 ins. deep respectively.

The only feature of particular importance about the frames lies in the manner of connection between the front and rear engines. In the experimental locomotive a plain pin connection at the point of juncture of the two connecting castings served as the means of connection. This pin was in triple shear when pulling, but was relieved of all strain when pushing, by the design of the connecting designs being such as to have corresponding contact faces, taking up all thrust independently of the pin.

The new method of frame connection is clearly shown in Figure 10, a plan view of the immediate vicinity of the connection. Essentially, the connection is similar to that between engine and tender, a built-up plate drawbar, 9 feet 8 inches long, as shown in the illustration, being used. This connecting drawbar is pin-connected at the rear end of the cross-bracing castings, between the cylinders. The faces of the castings, where they come in close proximity to each other at the inner ends, have a curved surface, with a radius to the centre of the drawbar pin. A concaved casting with similar curved surfaces acts as a filler, permitting a rolling motion between the front and rear engines when rounding curves. That is to say, the intervening piece so adjusts itself as the engine takes a curve that its centre is always in a line joining the two drawbar centres. This arrangement maintains a close alignment between front and rear sections, eliminating all play.

The drawbar was so designed as regards length that as the adjacent ends of the frames move outward when taking a curve, the centre of the drawbar is always in the centre line of movement, i.e., directly over the centre of the track, keeping the push or pull where desired, and overcoming the difficulties that would be experienced from side thrusts were the connections as in the original design.

Centering rods, to maintain the relative location of front and rear engines with regard to each other, are attached, one on each side of the connecting casting of the rear engine, these being attached by pins at the centre to the connecting casting of the front engine. as shown in Figure 10. The relative positions being thus maintained, the intervening distance casting has no tendency to jam in place.

When pulling, the front part of the forward engine of a Mallet has a tendency to lift, this condition being reversed when the engine is pushing. In this new design this undesirable feature is taken care of by means of bolts carrying compression springs passing down from lugs on the upper surface of the connecting casting of the back truck to similar lugs on the lower surface of the connecting casting of the front truck as indicated both in Figures 9 and 10. Thus, the connecting casting of the rear frame, through its bolts, carries the rear end of the forward frame when the front of the latter tends to rise, with a consequent depression of the rear end. The springs, mounted on the carrying bolts, absorb any quick fluctuations that may occur.

The spring rigging is of the usual type, equalized from front to rear on each truck The forward engine has a cross equalizer at the front, but the rear engine is merely equalized along the sides.

Cylinders and Motion Work

Both pairs of cylinders are of the piston valve type, with inside admission on the high, and outside on the low pressure engines. They are decidedly unique, forming a radical departure from the practice heretofore followed in Canada. The low pressure cylinder being typical of both, is shown in Figure 11.

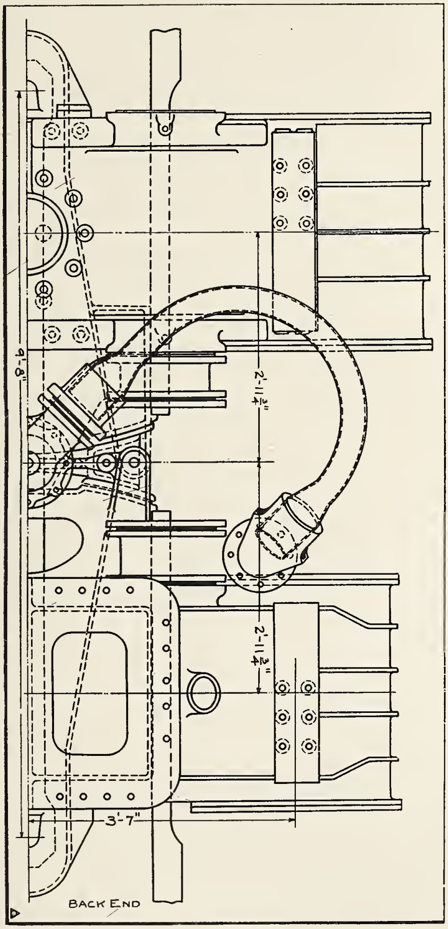

FIG. 10—Steam Piping on New Mallet.

The point of particular change lies in the fact that the cylinders are made of cast steel, lined with cast-iron bushings. Making them of steel saves a weight of no less than 6,000 pounds, which is a very important factor where weight elimination to obtain greater steaming capacity is desired. An examination will show how extremely light in construction the cylinder is, the shell being only five-eighth inch in thickness, with a corresponding high pressure thickness.

The cylinders are cast separately, divided in the centre line as usual. In the case of the high-pressure cylinder, there is a cast-steel saddle common to both cylinders and bolted to their top face, and to which the boiler is attached. The original low pressure had a small saddle bolted to the upper surface with a corresponding saddle attached to the boiler barrel, bearing upon it. In this design this support has been dispensed with, for, on account of the movement possible at this point, pounding occurred, which could be attributed directly to the bearing surfaces knocking.

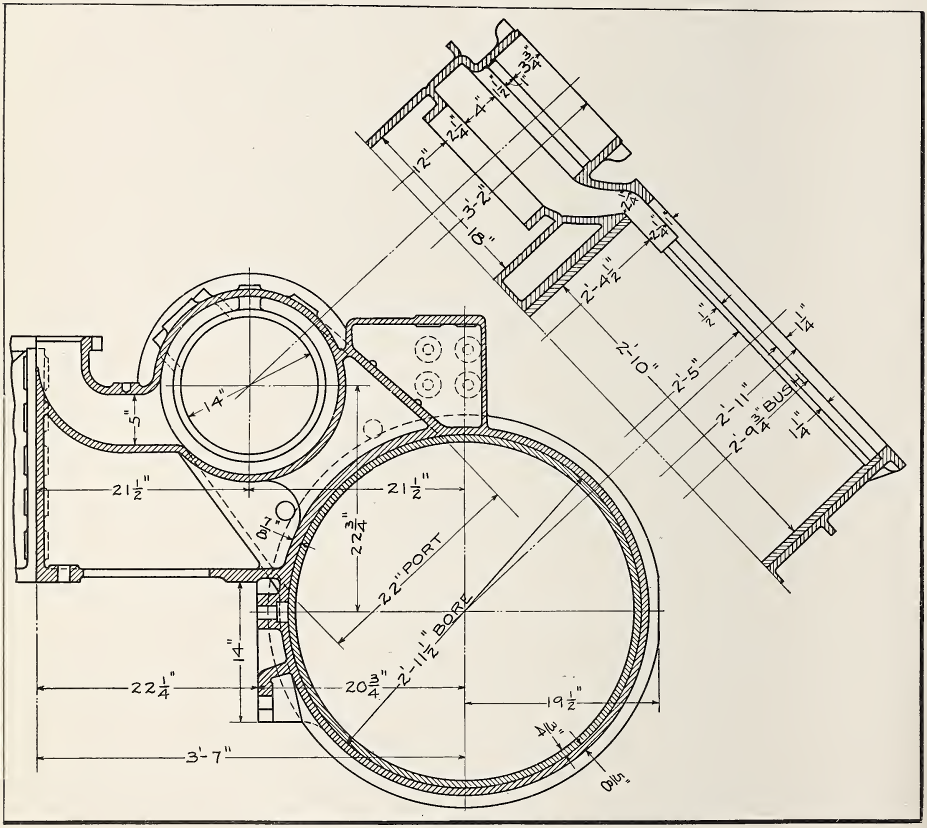

FIG. 11—Steel Cylinders of New Mallet.

The Walschaert valve motion is used on both engines, and is of the usual type to conform to Canadian Pacific Railway standard practice with inside supported trunnioned bearings dispensing with encompassing support. The front radius rod has a long suspension from the reach rod bell-crank, which, combined with a ball and universal joint at the lower and upper ends respectively, allows the engine to take curves without much distortion to the valve motion. When rounding a sharp curve, the boiler will swing about 9 inches off the centre line. This necessitates flexible joints. In addition, if the lifting link were short, it would swing over a considerable angle when on this 9-inch offset, resulting in a lifting of the radius link from its normal position. This would shorten the valve travel when in forward gear, and lengthen it when in backward. The length of link here shown is sufficient to make this feature practically negligible.

Provision has been made for changing piston packing rings by simply removing the front cylinder heads, disconnecting the main rod from the cross head and pushing the piston out into the space between the two cylinders. The piston valves have also been taken care of in a similar manner, so there can be no objection in this arrangement of cylinders on the score of inaccessibility.

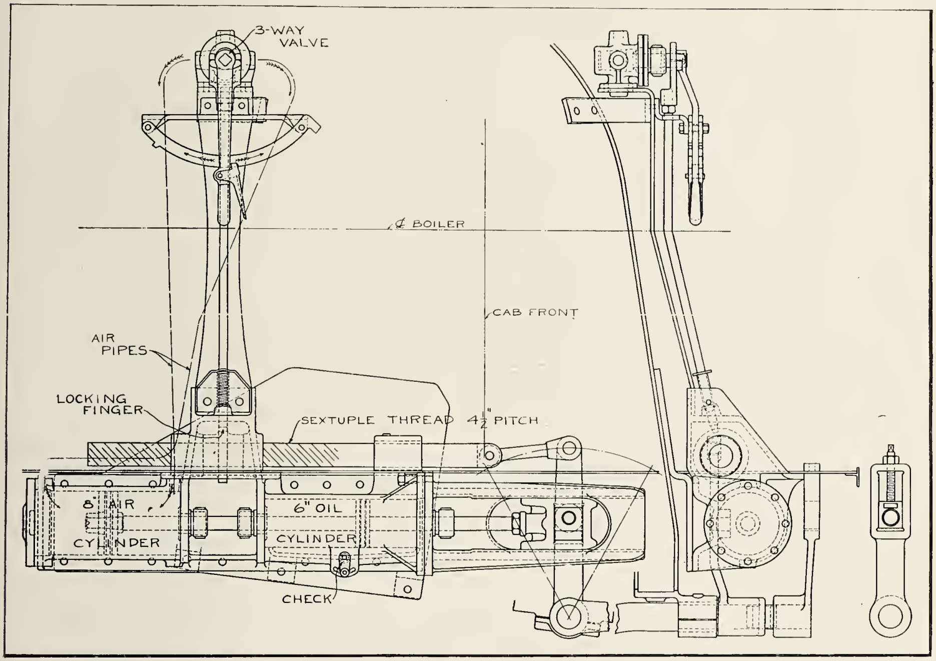

FIG. 12—Power Reverse Gear of New Mallet.

An ingenious mechanical reverse mechanism, shown in Figure 12, has been designed for this engine. The operating mechanism consists of an 8-inch air cylinder, dampened in its movements by a 6-inch oil cylinder with an adjustable by-pass connecting the cylinder ends. The crosshead of the machine is attached to a fulcrumed lever, the upper end of which is connected by a short link to a rod, threaded for about two-thirds its length with a sextuple thread, 4½-inch pitch. This threaded rod is guided, in bearings attached to the top of the air and oil cylinders.

Confined in the casting above the opening between the air and oil cylinders there is a nut fitting the sextuple threaded rod. The outer surface of this nut is notched to receive a dog from above. This dog is moved automatically by the engineer when shifting the gear by the air valve above.

The operation is as follows: Swinging the handle of the 3-way valve to the right from the notch on the quadrant, lets air into the left end of the cylinder. The same movement of the 3-way handle raises the dog which engages the sextuple-threaded nut. This is performed by a projection on the side of the handle near its point of suspension, engaging another projection on the dog rod. Otherwise, the piston would not move by the air pressure, the dog engaged in the nut locking the piston in place.

The air moves the piston to the right, carrying forward the cross-head and lowering the links. The forward movement of the piston draws forward the sextuple-threaded rod, causing the nut to revolve in its retaining casting. When the gear has moved to the desired location, the 3-way valve handle is brought back to its vertical position, which drops the dog back into the nut, locking the mechanism instantly in the desired location.

The mechanism is so designed as to make it possible to change the amount of motion of the low pressure gear, without disturbing that on the high pressure cylinder. The high pressure gear receives its motion directly from the fulcrumed lever moved by the air piston. On the same shaft as this fulcrumed lever there is keyed another lever, shown at the extreme right in Figure 12. This lever has a block adjustable a couple of inches by a set screw. To a pin in this moveable block the low pressure gear reach rod is attached. As shown in Figure 9, this reach rod, being too long for one piece, is made in three sections, with the middle section guided in bearings under the runboard near the centre of the locomotive.

Piping

A standard throttle valve located in the steam dome of the boiler supplies steam to a long dry pipe which runs forward to the front tube sheet. Here it connects to the saturated steam header, and after traversing the superheater tubes to the superheated steam header, branches out each side of the smoke-box, to a lagged pipe under each runboard, leading back to the high pressure cylinder.

The piping for carrying the exhaust from the header between the two high pressure cylinders to the low pressure cylinder header is quite ingenious. This piping is shown to the best advantage in Figure 10, which, in conjunction with Figure 9, clearly outlines the arrangement. The idea was to pipe the steam from the high pressure engine to some point on the low pressure engine that had no motion relative to the latter. Such a point exists directly over the point of connection between the two connecting castings. This was absolutely the case in the old design where a pin connection was employed. By bringing the exhaust pipe to meet the intake pipe of the low pressure directly over the pin-connected point, there is no motion between the two other than a slight circular one, allowed for by a swivel joint. In this new design, as the locomotive takes a curve, the new drawbar arrangement causes these central joints on both frames, to part as they swing outward due to the engine negotiating the curve. That is to say, the actual centre line of the locomotive lengthens—a case of two sides of a triangle being greater than the third.

The method of making these steam connections is as follows: The steam pipe, rigidly connected to the header of the high-pressure cylinder, is bent into a large loop as in Figure 10, the section of the pipe itself being first flattened into an oval section as indicated in Figure 10, the pipe thus assuming the shape of the tube of a Bourdon gauge. The other end is connected by a swivel joint to the low pressure header. Now, as the locomotive takes a curve, this central point of the swivel joint becomes further away from the corresponding point in the high pressure frame, by a fraction of an inch, causing the distance between the pipe connection centres to slightly increase. A solid pipe connection would likely break under such a strain, but having this pipe not only flattened, but also bent to a large loop, it contains sufficient flexibility to spring the necessary amount.

From the low pressure header, the steam passes through the cylinders and out through another swivel joint to the exhaust pipe. This contains another feature peculiarly different from standard Mallet practice, though similar to that of the experimental locomotive. The small side swing of the exhaust outlet of the low pressure cylinders (less here than even in the experimental locomotive, on account of the outlet being on top less than 3 feet from the point of swing), results in the elongation of this pipe being practically negligible. Thus the expansion joints in the usual design, capable of providing for extensions up to 1½ inches, are not necessary. Instead, the extension is compensated for by the sliding of the pipe flanges on the flat faces of the ball rings. The flanges are held in their seats by 10 springs of 200 pounds capacity each, or a total of 2,000 pounds. The exhaust from this point proceeds up the exhaust pipe.

Guiding Power of Front Engine

Guiding trucks have been dispensed with in this design of Mallet, it being believed that equally good guiding qualities may be obtained without their use. Their elimination reduces the wheel base and total weight, and the flange pressure is sufficiently low to safely warrant their absence.

In curving, it is the boiler body that offers the greatest resistance, and as the truck must swing laterally beneath it, it is supported partly by friction plates and partly by a spring suspended roller. The arrangement of these suspending means is clearly shown in Figure 13. As indicated, there are two main castings, one mounted rigidly on the frames and the other bolted securely to the boiler body. One half the weight of the boiler is carried on plain, flat friction plates attached to the faces of the two main castings. There are four of these, in pairs, the intervening space being occupied by the floating device. The friction plates have ample surface, and are provided with oil grooves across the surfaces, which, connected with an oil box in the upper castings, ensures ample lubrication.

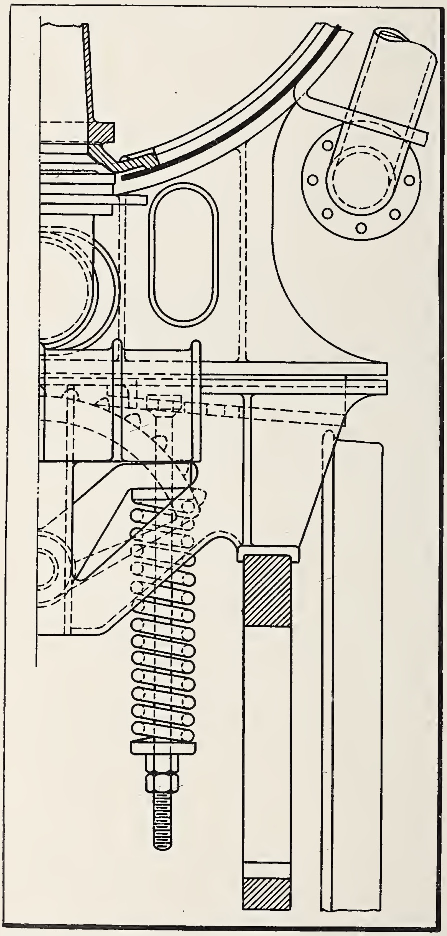

FIG. 13—Guiding Mechanism of New Mallet

In the intervening space mentioned above, the floating device is located. Two wedge-shaped pieces, as indicated, are secured to the lower face of the upper casting, one on each side of the centre. These wedges have two different slopes, the steeper one being at the centre. A toothed roller engages with similar tooth cavities in the lower side of the wedge plates, this in turn being mounted on a floating shaft carried by two cross equalizers to springs supported on bolts from the lower casting. Any side movement of truck as when the locomotive is taking a curve, causes the inclined surfaces to force the roller downward against the resistance of the supporting springs, which produces a force to pull the roller around the curve with the truck, and relieve the rear truck, to which the boiler is rigidly connected, from much of the strain, that would otherwise fall on the flanges of the leading pair of drivers of the back truck. The greater the side movement of the truck, the greater will be the reaction from the spring compression, resulting in a constantly increasing rolling resistance.

The frictional resistance of the flat friction plates decreases on taking curves, for, on account of the depression of the floating springs, a greater weight is carried by the latter part of the supporting mechanism, relieving the friction plates of a portion of their load, thereby decreasing the frictional resistance. The intensity of the assistance offered by the floating mechanism to the pulling of the front part of the boiler around a curve with the truck, may be varied at will by adjusting the compression of the spring by means of the supporting nuts.

In conclusion, it might be mentioned that Mallet locomotives are giving the greatest satisfaction wherever they have been employed. From a traffic standpoint, they are all that could be desired, as the foregoing remarks concerning both the roads in the United States and the Canadian Pacific Railway will have emphasized. Mechanically, they have proved themselves superior to locomotives of standard designs. Notwithstanding the fact that there are a great many joints, etc., the machine efficiency is higher than on older types. Viewed thermodynamically, the efficiency is also high, for both the principals of compounding and superheating are embodied without the objectionable complications met with in the use of cross compounds. The only question that now seems to exist in the minds of those responsible for these new machines, is the factor of maintenance after the locomotives have been in service a number of years and are approaching the age of decrepitude common to all machines. Opponents of this type contend that the multiplicity of parts will lead to a rapid deterioration. But as they have been in service such a short time, no definite data has been collected on that point. Present conditions being satisfactory, it remains for the future to develop their weaknesses.

[*Note.—Many of the illustrations used in this article appear by courtesy of "The Railway and Marine World," Toronto.*—Ed.]

CITY PLANNING*

JOHN M. LYLE

While the City Planning movement has been making rapid strides in Europe, in Canada, as yet, practically nothing has been accomplished in the way of comprehensive city planning. There are many signs, however, that at last the general public is being awakened to the great importance of this movement, and it is to be hoped that in the very near future all our cities, towns and villages will be replanned, and the new town sites intelligently laid out with a due regard to their future expansion.

It has been the custom of the past to have our cities and villages laid out by engineers and not by architects. This is, it seems to me, a very grievous error, and one that should be corrected if we wish to have our cities planned to advantage. A collaboration of the architect and engineer would give much better results; the architect's province being the general plan, the laying out of boulevards, squares, parks, etc., the studying of the problem from the point of view of circulation, transportation, parkway arrangement, the placing of public buildings, consideration of vistas, in short, the general scheme. The engineer should collaborate with the architect in the laying out of sewers, water mains, the working out of grades, the survey work, etc. The problem presented is essentially one of plan and, therefore, within the scope of the architect, who should, by his training, be better fitted for such a task, than a man who has had practically no training to fit him for the work that he is undertaking. If, in addition to the city engineers employed throughout Canada, the cities employed consulting architects on city planning, the results would, probably, be different.

Let us consider for a moment what are the principal points to be considered in the planning of a city. We might divide them roughly into the following:

1st. Circulation (streets, boulevards).
2nd. Transportation (surface cars, tubes).
3rd. Sewerage and water supply.
4th. Parks and parkway arrangements (monuments).
5th. Suburban lands.
6th. Markets.
7th. Water frontage.
8th. Slums, playgrounds.

Circulation

One would naturally suppose that when our cities were being planned, those responsible would consider the lay of the land, and make provision for not only a vertical and a horizontal circulation, but also for a diagonal circulation, and, possibly, a circular or belt circulation. On the contrary, we find an absolute lack of any consideration of the first principles of planning. The streets are laid out at right angles to each other. There are many blind streets, and the main arteries are, as a rule, no wider than the ordinary streets. That this type of city planning is stupid, uninteresting and impracticable to a degree, needs no demonstration. In order that the citizen can go from one section of the city to another with despatch it is necessary that not only should the streets run at right angles to each other but that there should be wide arteries provided to run diagonally from focal points of importance, and also circular arteries, linking up other points. Boulevards, possibly connecting park systems, should be provided of a greater width for pleasure driving and walking. There is a divided opinion among city planners as to the best width to make these different kinds of streets. For the purposes of this paper, we will designate the above mentioned as streets, thoroughfares and boulevards. The general concensus of opinion is that for residential streets the width should be 60 feet, for business thoroughfares 86 feet, and for boulevards 125 feet. It has been found a mistake to make a business street too wide. Eighty-six feet is suggested, as it would give ample clearance for two lines of street cars, a 20-foot roadway on either side, and a 12 foot 6 inch sidewalk on either side.

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*Read before the University of Toronto Architectural Club, January 29th, 1912.

Transportation

We come next to the question of transportation—a very vital one at present for the citizens of Toronto.

In considering this question, we will concern ourselves only with the different public systems of transportation, leaving out the private vehicle. To bring this part of city planning before you clearly, let us look at the transportation problems of our own city.

Firstly—We have the steam railroads.

Secondly—The radial railroads.

Thirdly—The street car system.

Owing to the fact that the railroads do not grant commutation rates, there is very little suburban traffic on the steam roads; and, owing to the fact that our radial lines come only to the outskirts of the city, there is not the travel on these lines that there would be if they were brought into the heart of the city. There remains the great carrying medium—the much abused Toronto Street Railway. While we feel that the service given us could be improved, the street railway company is not altogether to blame. The city is so badly planned that unless proper arteries are provided and the same supplemented by a tube system, Toronto need not hope for any relief for years to come.

It is absolutely impossible to get a rapid transit service on surface lines. If we desire to maintain the open character of residential Toronto and give every home a little plot of land, it is necessary to have the tubes. I, for one, pray that we may never see the tenement system in Toronto. In the heart of every Britisher there is inborn a love of home, the desire for a little place that he may call his own. Is this instinct to be fostered or to be blunted?

Have you ever stopped to consider what rapid transit means to a community of this size? There is a limit to the distance one can go with comfort on a surface car—none of us are anxious to become daily strap holders for three-quarters or an hour's ride. It is not only disagreeable, but it is a great economic waste—a waste of time and energy, which should be conserved to ourselves for our pleasure or our work.

Sewerage and Water Supply

These are essentially problems for the engineer. In passing, however, I might say that as a layman, it has always seemed strange to me that our intake pipe is situated where it is. Currents from the Niagara River and from the eastern and western gaps must surely affect it. Would it not be wiser to have gone fifteen or twenty miles below the city to secure a pure supply? It might interest you to know that the city of Hamilton in 1853 went eleven miles for their water supply, and to-day, as ever since, you can drink it from the tap.

Parks, Parkways, Monuments

It is estimated that in Canada eleven per cent. of the deaths from all causes are due to tuberculosis. Large sums of money are yearly expended in establishing and maintaining hospitals for the treatment of those afflicted with the dread disease—consumption, and the kindred tubercular maladies. Many public spirited men give of their time and means to this worthy cause. Would not much money and many lives be saved if more thought were given to precautionary measures? Can we not recognize that the modern tendency of population is towards the great cities, and plan for numerous parks, and squares—the lungs of a community—*just as essential* to a city as the lungs are to the individual.

Toronto is very badly off for parks. There is really only one park which is worthy of the name and that is High Park. The main argument against having additional parks and playgrounds in Toronto is the great cost of procuring the land. This is a very real objection and can only be met by the city acquiring control of the planning of suburban lands, and by laying out these lands with the fixed idea that eventually they are to become a part of the greater city. Then it would be possible to provide in advance for ample park and playground accommodation. It is commonly remarked that Toronto covers a large area. Compared with the German cities—she is nowhere. The city of Dusseldorf, with 300,000 inhabitants, has an area of 29,000 acres; the city of Cologne, with a population of 428,700 has an area of 28,800 acres; Frankfort, with a population of 335,000 has an area of 23,203 acres; Toronto, with a population of 400,000 has an area of 16,320 acres; in other words, but little more than half what the same sized German city would have. The reason for the great area of the German cities is their large park and parkway areas—they are veritable garden cities.

Parkways

The parkway is a feature of city planning which is comparatively unknown on this side of the water, yet it has great value in the general scheme of city planning. A parkway, in contradistinction to a park—is a strip of sward placed to the side of a thoroughfare. This sward is planted with trees and shrubs, and laid out with attractive flower beds. Benches are provided, while statuary and fountains are placed at intervals. Bridle paths and walks flank the central sward. These parkways are sometimes two or three blocks long and sometimes several miles. They are a most attractive feature, and an especially valuable one in a residential section.

We might to advantage adopt this idea in Toronto—having in our Rosedale Ravines beautiful natural parkways capable of embellishment.

Monuments

If the parks and parkways are the lungs of our cities, may it not be said that the statues, architectural monuments and arches are the outward expression of the soul of our community? Do they not express the ideals, the aspirations, and the hopes of our citizens? How important they are, we little realize. How they inspire the youth with high ideals of patriotism and duty. A concrete example of just this inspiring quality of the monument is the new South African Memorial just erected at the foot of University Avenue. Mr. Allward's fine work changes the whole aspect of the neighborhood—it stands a mute protest against commercialism; it stirs the imagination to thoughts of empire, home and country. It reminds us that there are other men who are empire builders, beside the much advertised commercial magnates of the day. May we have more monuments of importance to point the path of honor, and to remind us that we also have other duties beside those of our immediate fireside.

Suburban Lands

One of the greatest obstacles to city planning in this country is the absence of any power of control by the municipalities in the planning of the suburban lands immediately adjoining the cities which are in process of urbanization. Until legislation is enacted enabling the municipalities to control the laying out of these lands, our cities will be planned by the real estate speculator and not by the city planner.

Markets

We are all aware that the cost of living is high, and that there are many reasons for it. Perhaps our shopkeepers need a little competition. It is generally understood that canals are necessary to regulate the freight rates, and to check any undue tendency on the part of the railroads to increase their dividends. Would it not be a good idea if, instead of one central market, we had a dozen small attractive markets convenient to the housewife? We have neighborhood libraries and neighborhood banks—why not neighborhood markets?

Water Frontage

In Canada we imagine it is impossible to have our water fronts both useful and ornamental. Private interests have become so strongly entrenched that any suggestion of a change in policy is not given more than a passing thought. How different the attitude of other countries. Take for instance the water fronts of the German cities—such as Hamburg, Frankfort, Cologne, Dusseldorf, or the magnificent harbor and water front of Rio de Janeiro. Here we find the foreign architects planning their waterfronts with an eye not only to the utilitarian side of the problem, but also with keen regard for the aesthetic. Provision is made for various kinds of freight. Wide embankments are built with spur lines connecting with the main railway systems. Oftentimes four and five lines of railroad tracks are run out on the docks, and freight can be transferred directly from the ships to the cars. The docks are ample and provided with all the latest hoisting devices, both great and small. Large store houses with railroad connections are built. Everything possible is done to facilitate the handling of freight. Nor is the aesthetic side neglected. Wide boulevards are constructed along the water front, equipped with all the necessary facilities for the enjoyment of aquatic pleasures. Bathing pavilions, landing stages, and casinos are built.

In Germany, the water front belongs to the city, and that it pays to have a first-class municipal harbor equipment is certain. Take for example, the harbor development of Frankfort.

The city lies upon the River Main, which was not navigable for Rhine traffic. The city fathers borrowed eighteen million dollars and proceeded to deepen the River Main for several miles —they erected docks and handling devices. What was the result? Its harbor traffic increased one thousand two hundred per cent. in nine years' time. The first harbor became inadequate, and a far more elaborate programme has been entered on.

Slums—Playgrounds

Large cities mean congested areas of population. Congested areas mean slums; slums mean disease, degeneracy, crime and immorality. The product of the slum is an inferior citizen; inferior citizens mean an inferior race, and consequently an inferior nation. Hence the importance of adopting radical measures to forestall the growth of this canker of modern city life.

Does anyone doubt the baneful influence of the slum? Let him look at the besodden types of East London, or the dwellers in the poorer districts of any of the great European cities. Yes, and in any of the great cities of the New World. Let him go down to the lower East Side of New York and see the results of slum conditions.

As yet, in Toronto, we have only the beginnings in two or three districts of the slums of the future. These modest efforts, however, promise well for the future growth of "Slumdom." We already have many wretched hovels and cellars which house numbers of families, where sanitary conditions are set at naught, and where both sexes are herded together indiscriminately.

How is the slum to be fought? By eradicating one of the greatest evils in city life—overcrowding. By forcing the property owners to conform to a general scheme for the development of the whole community. By eliminating narrow streets; by enforcing certain regulations as to the number of families that shall occupy a given house. By restricting the height of a house. By providing playgrounds and parks within easy walking distance of every home. By enforcing the regulations that no more than a certain percentage of the land shall be built on. If these ordinances were carried out we would be safeguarded against the growth of slums in our midst. Especially would this be true if the last mentioned regulations were enforced.

In the German cities the regulations in regard to the area that can be built on are very stringent. Take for example the city of Cologne. Here we find that a prospective builder in the business section can only build on seventy-five per cent. of his land; in the second building area on sixty-five per cent.; in the third area on fifty per cent., and on the outskirts on only forty per cent. of his property. It will readily be seen that such regulations would make for the beauty, health, comfort and happiness of a community. It might be urged that in enforcing such strict regulations that the property owner was not being fairly treated. Experience has proven the contrary. If a neighborhood is protected by certain building restrictions, as a rule the property has a proportionately greater value.

Playgrounds

One of the greatest enemies to the slum is the public playground. It is well known by penologists that the criminal is made in his youth. It is also well known that the criminal product of the old world "slum"—the descendant of perhaps several generations of criminals—is one of the most difficult of men to reform. If the youths of our crowded districts have no place but the streets to play in, it does not take a vivid imagination to picture the evil results to both health and morals from such a condition of affairs. New York has recognized the importance of playgrounds for her congested districts. She has already laid out several squares fully equipped with shelter accommodation and with gymnastic appliances and space for open air games. She has also provided large recreation piers on both the North and East Rivers. These piers extend out into the river and are double decked as it were—roofed in above and open on the sides. It is, indeed a sight to see the crowd of mothers and children in one of these pavilions on a hot summer's afternoon.

In respect to playgrounds, Toronto is ill equipped. Would it not be possible for the city to create a series of playgrounds? They are sadly needed.

What Germany is Doing

From time to time I have had occasion to refer to Germany and different German cities. You will, perhaps, be interested in knowing what Germany is doing in the matter of City Planning.

Of late, we have all read much of Germany in the press, in books, and in magazines, and many are the speeches where the "German Bogey" has been pictured in glowing terms to a sympathetic audience. We have read of dreadnoughts until the word has become a positive nightmare. We have even a golf club called "The Dreadnought."

In all the discussions that have taken place but little attempt has been made to analyze the reason for the great progress that Germany has made in the immediate past, and is making to-day. Could we not learn some lessons from this enterprising, aggressive people?

If we were asked, what more than anything else had contributed to Germany's greatness, the answer would probably be "education" and "legislative foresight." Germany more than any other country has recognized the importance of looking ahead to the welfare of her future citizens, and by wise legislation is solving one of the greatest problems of the day—the planning of the city. Her farseeing statesmen have realized that modern life has changed the conditions under which great masses of her people live. They have seen that great numbers are gathering together in large centres; that the cities have grown at the expense, oftentimes, of the country, and they realize that great cities have brought consequent evils; slums have grown up, crowded districts have become a menace to the health and morals of the nation. They have found that the old haphazard planning and the old method of handling civic problems have produced results which are affecting the well being of the whole nation, the health and happiness of her people. She has realized that unless her citizens are strong and healthy, it would be useless to have a large army or to build huge dreadnoughts, if she did not have the right men to form her battalions or to man her ships.

Germany has, therefore, undertaken to enact legislation making for the proper laying out of her great cities to a general plan, having in view such arrangements for transportation, parks, parkway system, location of schools, fire-halls, as would give to future generations the advantages of a well ordered community.

Is this not surely a *great imperial idea?* Could we not in the British Empire awaken to the needs of such legislation? Contrast the large German cities like Berlin, Munich, Dresden, Dusseldorf, Mannheim, Frankfort, Cologne, Weisbaden and Stuttgart with the cities of this country, or in fact, of any other country. What do we see? On the one hand, we have the Germans attacking the problem in a scientific and rational manner; expert architects plan their cities, expert engineers lay out their sewers and grades, experts in hygiene report as to conditions affecting this branch of civic work —and on the other hand we have nothing but bungling and haphazard planning.

They are not only considering the people of to-day, they are thinking of future generations; they are studying the problem of City Planning as they are studying the problem of their army, their navy, their mercantile marine, or their manufacturing interests.

Private interests are not allowed to dictate terms to the detriment of the whole community. Water rights are preserved for the benefit of the people. The speculative builder is restrained. In short, the problem of city planning and city government is treated as a business proposition, and order and control are evolved out of chaos and uncertainty.

The plans are prepared on the most complete and elaborate scale, having in view the growth of the city. Streets, boulevards, parkways, school houses are laid out far beyond the city limits, sometimes to a distance of thirty miles.

We would study to advantage the policy of land ownership as adopted by the German cities. The result of this land ownership is that the German cities are enabled to finance their schemes for civic improvement; they can control the surrounding territory which is in process of urbanization.

It has been so successful that there are 1,500 small towns in Germany where the revenue derived is so great that there are no local taxes whatsoever. There are five hundred of these towns where not only are there no taxes but a dividend of from $25.00 to $100.00 per year is paid to each citizen as his share in the earnings of the common lands.

The Importance of a Fixed Policy in Regard to City Planning

Time has wrought many changes in France since Baron Haussman inaugurated under Napoleon III his scheme for the rebuilding of Paris. The form of government has changed from monarchy to republic; mayors and city councils have succeeded each other, but despite the many changes in administration, we find the same policy of replanning being steadily carried out after the original scheme, as planned by Baron Haussman in 1853.

Washington is another example of many where a city is being developed along the lines of a well considered and comprehensive plan made by the great architect L'Enfant in 1791.

We know that London, Paris, Berlin, Rome, Washington, New York, Cleveland, Rochester, Kansas City, Frankfort, Cologne Dusseldorf, Genoa and many other of the great cities of the world are replanning their cities, and are providing in an intelligent manner for the future growth of their different communities.

While it is true that Germany is leading in the art of city planning, it must not be forgotten that England also is awakening to the importance of the well planned city. Especially in the development of garden or model suburban towns is England making progress, the two garden towns of Port Sunlight and Bournville being laid out in the most intelligent and attractive manner—the work of two English architects. London is spending millions of pounds in cutting through avenues and streets; she is doing to-day what was advocated by one of the fathers of city planning—Sir Christopher Wren—the famous architect, just 246 years ago. No better illustration could be found of the stupidity of a people in not recognizing the self-evident advantages of a well planned city. It is probably costing the city of London as much to-day to cut through one little street as it would have to lay out the whole scheme as planned by Wren in 1666. It will surely interest many to hear something of Wren's plan for the rebuilding of London after the Great Fire; if his scheme had been carried out, London would have become the wonder of the world.

Sir Christopher Wren was commissioned by King Charles II to prepare a plan for the rebuilding of the city of London. He proposed to widen the streets, to create two large circles with radiating streets and connecting avenues, to form public places into large plazas; to unite the halls of the twelve chief companies into one regular square annexed to Guild Hall; to make a commodious quay on the whole bank of the river from Blackfriars to the Tower. The streets were to be of three magnitudes—the principal streets running through the city to be 90 feet wide, the secondary streets 60 feet, and the lanes 30 feet wide.

The Exchange was to stand free in the middle of a plaza, and to be, as it were, the centre of the town, from which the 60 foot streets should radiate to all the principal parts of the city. Many streets were also to radiate upon the bridge. The streets of the first and second magnitude to be carried as straight as possible and to centre into four or five plazas. The quay or open wharf on the bank of the Thames to be spacious, and provided with ample warehouse and docking facilities. He proposed to rebuild the parish churches in such a manner as to permit of them being seen at the end of every vista. He further proposed that a wide avenue be constructed from Oldgate to Temple Bar in the middle of which was to have been a large square capable of containing the new Cathedral of St. Paul's—the Square to be large enough to afford a view of the building from all points. What a comparison between the splendid square and the cooped-in aspect of this magnificent church of to-day.

Should we not profit by London's example and take to heart her lesson for ourselves? Does it pay to spend money on the beautifying of a city? Most emphatically "yes." Take away from any of the European cities their beautiful monuments, parks and avenues, and where would the millions of tourist money come from? Make Toronto not only a healthy city but a beautiful one and the money from abroad will pour into the coffers of the merchants of King and Yonge Streets.

Should we not remember that a beautiful and well planned city is not only a source of pride to its citizens, but a great factor in the upbuilding of the empire—a power for good in the world, one that makes for the prosperity, health and happiness of millions of human beings.

POINTS CONCERNING PRODUCER PLANTS

By C. F. Publow, B.A. Sc.

[*The following article, descriptive of producer plant installation and operation, contains a valuable amount of detail not ordinarily found in writing. An attempt has been made to enumerate numerous small and lesser important points that constantly arise. They are often omitted as superfluous to the reader well informed in power house operation. There is a tendency to overlook the need of the undergraduate and his inferior knowledge of practical points. The aim of the writer of this article has been to supply information that will lend itself to easy assimilation on the part of the student, referring frequently to the particular installation of which he is in charge.*—Ed.]

The engine and producer plant which has been installed in Davidson was manufactured by Daniels, Strand, Eng., and it consists of a producer lined with fire brick, and its vaporizer; a water heater, for the water flowing into the vaporizer; a hydraulic box or washer; a scrubber filled with coke and having a spray of water entering at the top and running out at the bottom; an expansion box containing a quantity of excelsior; and lastly, an engine of the four cycle type, with throttling governors. This engine is specially designed for electric lighting work. Its frame weighs approximately three tons, exhibiting a marked difference between steam and gas engine practice for the same power (36 b.h.p.). Its flywheel is 7 ft. 8 ins. in diameter, with a 12-inch face, and weighs approximately three and one-half tons, showing what an extremely heavy wheel is required to give a constant angular velocity of itself due to only one working stroke in four. The speed of the engine is 220 r.p.m. It is belted to a 30 K.V.A. 3-phase Westinghouse alternator, 60 cycles. This in turn is belted to a 2-K.W. Westinghouse exciter.

As is the case with any plant, the object of a producer plant and engine is to convert the heat energy due to the combustion of a fuel (anthracite coal in this case), into mechanical energy. In their methods of accomplishing this, engines divide into two classes: (1) *external* combustion engines, the steam engine being a well known example, where we have complete combusiton of fuel entirely separate from the engine, and use a working fluid; and (2) *internal* combustion engines, gas and gasoline being examples, where part at least of the whole combustion occurs inside the cylinder, and thus acts directly to drive the piston. The producer plant and engine belong to the second class. Partial combustion occurs in the producer, where the fuel is transformed into gas, and this gas is led through the scrubbers to the cylinder, where the combustion is completed, supplying the energy in mechanical form. It is in the direct conversion of heat energy to mechanical energy that this type of engine finds its great fuel economy.

Producer plants are divided into two groups, to which the terms "pressure" and "suction" are applied, "pressure" where the air required for the generation of the gas is delivered to the gas producer under pressure derived from an auxiliary source, the gas generated being then delivered to the engine under the same pressure; "suction" where the suction stroke of the engine causes the draft which generates the gas. The plant in Davidson is of the latter type.

A few outstanding points regarding this type, and applying in part to all internal combustion engines, are worthy of note:

(1) The conversion of heat energy into mechanical energy directly in the cylinder as previously mentioned.

(2) Little water is required to operate it.

(3) There is no danger of explosion, the gas being generated only as required.

(4) There is no occasion for any more specially skilled labor to operate than in the case of the steam engine.

(5) The space per h. p. is relatively small, including the whole plant equipment.

(6) In fuel it is extremely economical.

(7) In the matter of starting, the time required is short. On several occasions we have had this plant in operation within five minutes after starting to blow the fan.

(8) Small consumption of fuel is required during standby.

It will be seen from the above that these conditions comply favorably with the demands of Western Canada. Fuel is expensive, and water scarce in many places. Skilled operators are hard to secure and wages are high.

Erection

In the erection of our plant concrete was used for the foundation throughout. Special care was taken in proportioning the mixture used, this being considered as demanding more attention than ordinary cases.

Regarding the placing of the foundation bolts for the engine, it was decided they should go down to at least within one foot of the bottom, the depth of foundation being governed by nature of soil and heaviness of engine. Care must be taken that they are left sufficiently high as they can be cut off after the engine is in place. They should be placed with great precision and checked well. To compensate for any slight error due to displacement while filling in, they are placed in pipes that are ½-inch larger in diameter than the bolts. It is good practice to get the whole foundation constructed in a short lapse of time so that the whole will set simultaneously..

After the frame is placed on the foundation leveling must be looked after. Iron wedges were used for the purpose in this particular plant. The type of engine has two shafts, both horizontal, one at right angles to the other. The cylinder must be slightly inclined towards the crank shaft, otherwise the lubricating oil is liable to accumulate in the combustion chamber and cause trouble. A good practical test for levelness of crank shaft is that when the bearings are tightened down, the shaft turns free and drops of its own weight. At this juncture care must be taken in tightening the frame into position as there is a liability to strain it. This might easily throw the main bearings out and cause trouble. Also, in

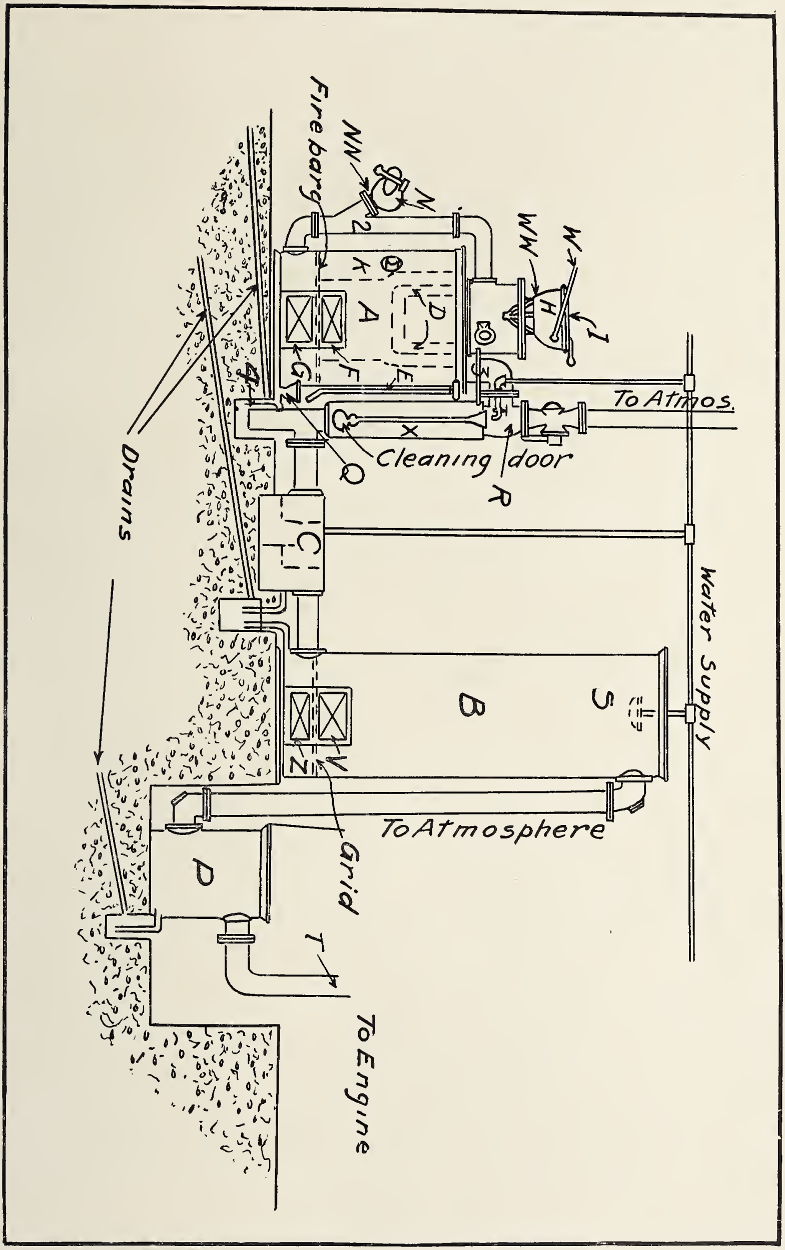

FIG. 1—PRODUCER DETAILS.

A—Producer. F—Fire door. G—Ashpit door. D—Vaporizer. H—Hopper. I—Hopper lid. W—Lever. WW—Valve in hopper. K—Air supply pipe. 2—Pipe to convey saturated from vaporizer to below the grate. L—Air supply valve to vaporizer. 3—Vaporizer feed water pipe. E—Vaporizer overflow pipe. N—Fan. NN—Fan valve. Q—Opening to supply ashpans with water. 4—Ashpit drain pipe. C—Hydraulic box. B—Scrubber. S—Water spray. P—Expansion box. R—Test cock at producer. T—Test cock at engine. X—Heater placing the cam shaft in position the proper cogs must mesh, otherwise the timing of cams and spark will be wrong. The engine is water-cooled by the thermo-syphon or gravity systems. Care was taken to have circulation as free as possible and to this end sharp angles in the hot water pipes were guarded against, and a gentle rise from bend above the engine to the tanks aimed at. Since hot water is lighter than cold, it follows that the higher these cooling tanks are above the level of the cylinder the better the circulation. The hot water flows in at the top, and the cooling water leaves from the bottom. Where there is a number of tanks the hot and cold water should be kept as far apart as possible. The tanks may be connected either in series or parallel. This cooling system requires but little water, and for small sizes of engines is very efficient. Valves are inserted to control the circulation and to permit the draining of the cylinder, during cold weather, if found necessary. To aid in draining, an air vent is also put in to prevent air locking. It also serves to prevent air locking during ordinary starting up and shutting down each day. Care must be used in seeing that the water in the tanks is well above hot water outlet, otherwise circulation is interfered with, and, perhaps, entirely stopped.

Engine Connections

In connecting up the gas plant to the engine, cast pipes were used. This required starting from the engine and working back to the producer, temporarily blocking each part in its place, so as to allow for any alterations which might later be desired. Care was taken not to use wooden blocks in places where there was a likelihood of any excessive heat, as the blocks are grouted in when the foundations are built.

Hydraulic Box and Seal Pots

When erecting the hydraulic box see that the overflow pipe is set to keep the water at the proper level in the two parts so that gas will bubble through constantly. If the overflow is too high the water will seal it for a time, and then the gas will "rush." The result is that it will be unsteady and poorly washed. Again, if the pipe be too low the gas will not be thoroughly washed or cooled. These conditions effect the operation of the engine very seriously.

With regard to the placing of seal pots, attention must be given to insure the required fall, otherwise the suction of the engine will "hold up" the water and soon flood the parts sealed, causing a great amount of trouble. Mention of this feature will be made later.

Starting the Producer

In starting a fire in the producer, oily waste and kindling wood, followed by a careful application of small quantities of coal, produce quick and effective heat, the fan being in operation before coal is supplied. An even layer of burning fuel upon the grate is desired, otherwise the entire effective heating surface will not be utilized, and the unburnt air which would leak through the dead coal will deteriorate the quality of the gas produced. A bed of live coal, three or four inches thick prepares the producer for additions of fuel in large quantities. The producer on the Davidson plant has a capacity of approximately 150 pounds fuel, but the engine requires a much smaller quantity for beginning operations.

To get gas either from new fire or standby, the slides are closed so that air from the fan is forced under the grate and up through the fire. Also, there must be water in the ash pan under the grate. This produces steam for the gas, enriching it.

At first the gas is poor and is allowed to escape directly to the atmosphere from the producer. A test cock is placed upon the producer to ensure a sufficiently good quality before beginning operations. When good gas is obtained (recognized by its violet-rose flame, its great heat, noiseless burning and no tendency to blow out) the atmosphere valve is closed, and the gas is forced through the rest of the plant.

Near the engine is a secondary test-cock which is lighted, in its turn. If the flame produced shows gas of desired quality, the atmosphere valve at the engine is closed and all is in readiness for starting. Now in the other parts we may have air, stagnant gas, or both, neither of which are useful. To eliminate them an atmospheric pipe is placed close to the engine, and through it these undesirable gases are blown.

While blowing up the fire to generate gas, the engine is put in readiness, by seeing that the spark is retarded, the cams arranged to give half compression, (i. e., the exhaust valve opens on the compression and exhaust strokes), the air valve set in starting position, which has to be found by experiment after the plant is erected; and as we start by compressed air, the engine must be placed on the expansion stroke just past the inner dead centre. At this setting all valves are closed, and the return stroke being exhaust, the cylinder frees itself. The compressed air tank is then opened and air applied to the piston. As the air is at approximately 100 pounds pressure, we can use its expansion qualities, thus saving air. To do this apply it during about half the stroke. After the engine has gone two revolutions it is again in the starting position, and air is again applied during the half stroke. By this time the engine has quite a considerable momentum, and by turning on the gas, it draws in a charge on its suction stroke. The explosion of this charge imparts the momentum. This tendency to "pick up" on half compression is a good indication of the proper mixture and spark setting. The engine is then placed on "full" compression and the spark gradually advanced until the engine attains its working speed. Once the engine starts, the fan is shut down and the slides opened so as to allow the proper suction, with which to make its own gas. We have found it a good practice to get the engine up to "speed" as quickly as possible so as to give it a large momentum. Then, if there happens to be any failure in the gas supply, it will have enough momentum to draw sufficiently on the plant to make its own gas, and not slow down. Once explosions cease in a case like this, it indicates a failure of the gas, and to aid the engine we make the whole of the suction charge a draw on the plant by closing the air valve.

When the engine starts, washing water should be turned on in the hydraulic box, and in the scrubber.

Once the engine is running on its own gas the mixture requires adjusting from starting proportions. It is found that the engine-made gas cannot be lit at the test cocks, it being of a very much poorer quality than that obtained by blowing. An explanation of adjusting the mixture will be given when the governing device is under consideration.

Recharging Air Tank

When the engine is "away" on its own gas, it is time to recharge the air tank. Now the producer is in a very active gas-forming state, and as we only require air in the tank, the gas admission valve has to be closed and the atmosphere valve at the producer opened to allow part of the gas generated, while recharging the tank, to escape. Otherwise it would accumulate and explode, being hot and mixed with air. No particular damage occurs from these, but as they are easily prevented, it is best to do so.

To charge the air tank we use the compression stroke of the engine, and to aid in getting it done quickly we once more use a maximum admission valve opening. Care must be taken to allow no burnt gas into the tank as the heat from it ruins the springs in the valve arrangement by rusting them very quickly. When the tank is recharged, or the engine's speed gets low, we discontinue the operation. First, the air valve is closed and the gas valve opened to allow a few strokes on the gas alone, so as to draw off quickly any accumulated gas, preventing the explosions in the producer referred to above. Then the mixture is adjusted and the atmosphere valve at the producer closed. This recharging process must be repeated until the tank is full.

History of the Working Fluid

With the engine running, a brief history of the working fluid might not be out of place. Air is drawn in over the top of the vaporizer where it mixes with steam. From here it is drawn under the grate. In passing through the heated grate it first burns to CO_2 and later, being still in contact with red hot coal, it absorbs another atom of C forming CO, a combustible gas. The steam also passes up through the fire and is decomposed, the hydrogen remaining free and the oxygen uniting with the carbon to form carbon monoxide. The gas is now very hot, and contains many impurities, both gaseous and solid. It is now drawn to the top of the producer, giving up part of its heat to the vaporizer, where the steam is formed. It leaves the producer by passing downward through the heater, where it again loses heat (used to heat the water flowing into the vaporizer).

At this point a turn is made at right angles to the washer, where the largest solid matter is deposited into the seal pot. In the washer the gas makes two complete circuits. Required to bubble through water twice, it is washed and cooled. From here it enters the scrubber and passes upward through the coke, which absorbs the ammonia, sulphur, tars, etc. The scrubber water, in trickling down carries away these impurities, thus keeping the coke in working condition. From the scrubber the gas is drawn into the expansion box, which is close to the engine, where any moisture which it contains is deposited and collects at the bottom of the box, to be drained off every day. From here the engine draws the gas into the cylinder through the admission valve, together with air, the two mixing as they enter the clearance chamber. After the charge enters the mixture is compressed, fired, and after doing work during the expansion stroke, it is exhausted to the atmosphere, chiefly as CO_2 and H_2O. It must be remembered the nitrogen of the air has been present through the chemical changes in the cylinder, but, as it is inactive, it is left out of consideration.

Operation

In operating the producer should be kept full or nearly so, otherwise air is drawn in at the hopper, spoiling the quality of gas formed. Steam being a great clinker preventative, as much as possible is passed through the fire. To this end water is kept in the ash pan at all times so that we may obtain steam from radiation of the grate bars. If the load gets very heavy free air may be required to be admitted, so as not to deaden the fire with too much steam. Attention must be given to the condition of the grate bars, so as not to allow them to decrease in temperature, for then the fire rises in the producer, and is not sufficiently deep to cause all of the CO_2 to form CO. This seriously injures the gas. We must also maintain the coal in a solid mass, as clinker in the body of it along the fire brick allows the gas to pass quickly in large quantities, thus lowering its quality. These clinkers must be broken up and removed.

The vaporizer must never be allowed to become dry or it will burn out very quickly. It is best to have it on the point of overflow at all times. During operation water must be kept running through the washer in such quantities as to just allow it to become warm, and sufficient water is required by the scrubber to keep the coke clean.

Forced feed oiling is used on the cylinder and piston, it being injected at the top of the cylinder by means of an oil pump operated by a cam on the cam shaft. This cam is capable of adjustment and the question naturally arises, when is the best time for it to operate. The lubricating oil is burnt to a certain extent during the expansion stroke, and thus looses at least part of its lubicating qualities. Again, since it has the whole piston to lubricate and is forced in at only one point, it must be given as much time as possible to spread before the explosion. The best time to pump oil in is evidently at the beginning of the exhaust stroke. This allows the oil to be spread all along the top of the piston, and gives it the time required for the admission and compression strokes in which to spread before the explosion occurs and decreases its efficiency by burning.

It must always be remembered while operating that as much work as possible should be obtained from a quantity of coal. This implies that the quantity of gas used must be made to do a maximum amount of work. To obtain the maximum efficiency of the gas requires just the required amount of air to get an explosive mixture, such that, under the conditions in the cylinder, it will do the work necessary without consuming extra gas, thus causing the smallest draw on the plant.

Again, to have the engine, with a working stroke in every four, exert a more uniform torque, will mean more uniform speed and smaller impulses. To obtain this we require the same charge in each suction stroke, *i. e.*, the same admission valve opening, which necessitates the same pulsation of the throttle governor.

On the particular engine to which we have so frequently referred in this article there is an adjustable spark, with positions ranging from starting at 5° late to running at 46° early. Thus, with the spark set in running position (advancing the spark has the same effect as making the mixture richer, providing it is "lean," and that is a higher compression pressure and thus greater expansion), we can adjust the air valve so as to give a mixture which will maintain a steady speed, and take in the same size of charge on each suction stroke.

Difficulties and Remedies

The best time to build in the fire brick lining of the producer is after it is erected, using just sufficient thin fire clay to make them air tight. If built in earlier there is a great danger of the bricks becoming cracked and the fire clay broken. This can be overcome to a great extent by pointing them up or better grouting them in, just before setting up.

The particular coal in use requires its own method for handling the clinker, as quality of coals differ greatly. We have found that a large quantity of steam is required to keep the fire cool enough to prevent the formation of clinkers. Again steam is very helpful in allowing the ash to clinker, but not harden, which admits of easy removal. To clinker well we allow three to four inches of ash to collect on the grate, taking care not to let it set until just before drawing, otherwise all the draft would go up through fire in just a few places, a very undesirable condition. As the plant is relatively small, only a small amount of gas is on hand, and the clinkering must be done quickly, leaving the door open only a short time. When slicing the grate bars to free them from small clinkers and ash, if there is plenty of water in the ash pan, the red hot coals falling through causes a good quantity of steam to be formed to keep up the quality of the gas.

On erecting our scrubber the seal pots were set too high, causing some trouble. The suction of the engine was sufficient to "hold" water in the scrubber with the drop it then had. Thus the space below the coke grate flooded. Under these conditions, on the suction stroke of the engine, the whole body of the coke was lifted, causing a rumbling noise. This lifting and falling of the coke broke it up and caused it to fall through the grate and into the seal pot, choking it up. Upon closing the gas valve the suction on plant ceased, and all the water in the scrubber came out, overflowing the seal pot. This was remedied by placing the seal pot from 6 in. to 12 in. below the bottom of the scrubber.

The easiest way to test if the valves are seating properly is to try the engine for forward and back compression both at "full" and "half" and at the same time to notice the running of the engine, assuring oneself of the condition of bearings, piston and rings. If the compression is not good, trouble may be looked for at either of the valves or the gaskets in the admission valve.

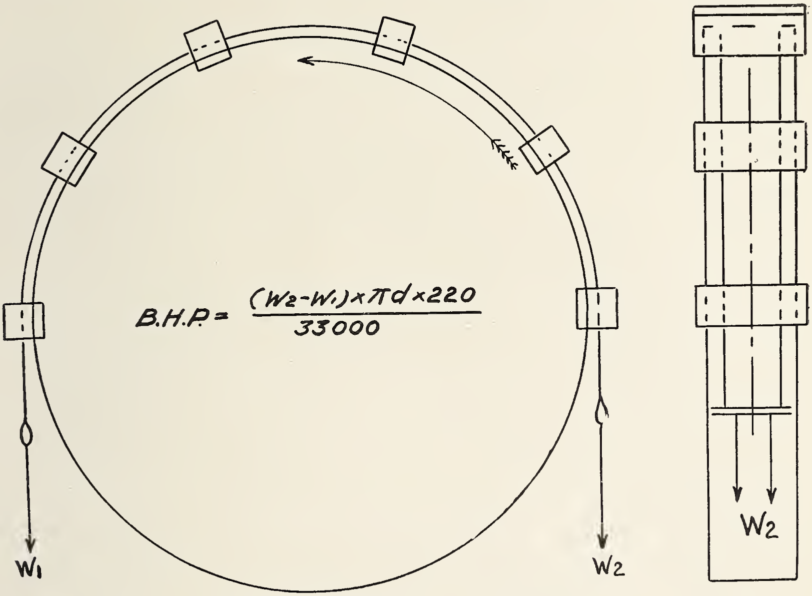

FIG. 2—Showing Adjustment of Brake.

In this engine there is a vent valve placed in front of the exhaust, the opening of which, when the engine is running, allows the cylinder to become practically free from all burnt gases. This aids in overcoming pre-ignition, due to hot gases igniting the incoming charge. It has a tendency to become gummed very easily, and this foreign substance is difficult to eradicate. We wait until closing down and open the valve to allow the engine to blow out the mixture.

If the fire gets very hot due to heavy load or from blowing a long time at starting, it bakes considerably. This must be kept broken up, which also helps to prevent the fire "hanging" by keeping the coal compact, insuring more uniform gas.

When the fire becomes hot, it often causes the vaporizer to boil, emitting great quantities of steam, at times enough to supply the suction due to the engine running. This means that practically all steam is drawn through the hot fire and hence we get a gas which is very rich in hydrogen, which explodes very quickly. At such times, unless more air is admitted into the mixture, or the spark retarded, we have an occurrence known as pre-ignition. The same trouble is caused by shaking the grate when it is still in good condition. The hot coals fall through into the water in the ash pan and cause a large quantity of steam to be formed. In the ordinary running we have noticed a "knocking" or "pounding" in the cylinder. This is due to high compression pressure, and it places a very heavy strain on the crank and connecting rod. It is caused by the mixture being too rich for the spark position, and can be remedied by retarding the spark, or better and with more economy, reducing the richness of the mixture by opening the air valve.

Our spark plug required some repairing and in doing so a little asbestos was left in a hole exposed to the heat. After starting we noticed a good deal of pre-ignition. On examination we found the asbestos to be the cause, and upon removing it no further trouble ensued. This emphasizes the care which must be taken to allow no foreign material to enter the cylinder and clearance chamber.

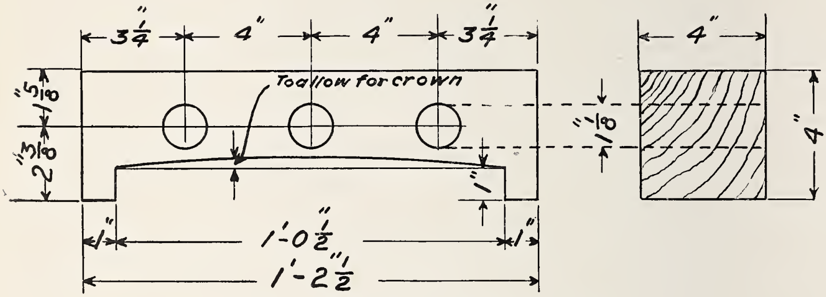

FIG. 3—Brake Shoes Used in Test.

When shutting down allow only enough draft through the producer to keep the fire alive, otherwise there will be large standing losses in fuel. Also see that all water is turned off except into the vaporizer, which must be kept full.

Tests

After the engine was started and had been running for a short time we wished to test it to see if it actually was up to its rating. We had no actual load sufficient for the purpose. One had to be devised. As this may be helpful, at least suggestive, to one in a similar position, a detailed description follows.

We first took an ordinary coal oil barrel and nailed three side blocks on the inside of it at the top, approximately 120 degrees apart. Into this was hung three pieces of ½-inch gas pipe, connected to the three phases of the generator through the switch board. The barrel was filled with water to cover the ends of the pipes about one inch. The plant was started up and brought to speed. With the field as small as possible giving us approximately 500 volts, the line switch was thrown in. The voltage dropped a little and the load was approximately 10 amperes per phase, after the phases were balanced by getting the pipes equal distance from one another. In a short time the water began to boil, causing considerable noise. Soon the effect of the evaporation began to be apparent in the current lessening and voltage rising. At this point we adjusted the rheostat, raising the voltage and thus increasing the load. In a very short time we were able to shut down the engine by overloading. At this point the voltage was approximately 1900 volts and the noise at the barrel was almost deafening due to the violent boiling. At no time was there any tendency whatever for the terminals to arc across. With the addition of a little water flowing in we could hold the load practically constant and thus maintain continuous operation.

From our readings we found the load on the generator, and estimating the losses due to efficiency of the generator, the load on the exciter and loss in belts, we approximated the B.H.P. of the engine. As the result was below rating, it was decided to make a brake test. This also proved very successful and interesting, and a description may be helpful.

In making the brake three pieces of one inch rope were used, held in their relative positions on the wheel by six pieces of wood as shown in Fig. 2. These pieces were nailed to the rope to prevent them drawing out of place. The ends of the rope were fastened to a short piece of pipe, all three ropes being the same length. These pipes made a convenient place upon which to hang the weights required for loading.

For weights anything solid was used, anvils, hammers, etc., being our choice, the weight of each piece being known. Two 25-pound spring balances were also obtained to allow for readings. When placed on the wheel we tied it down so as there would be no danger of it going over.

Once the engine was started we greased the wheel and then loaded it up. We had it well loaded for two hours and owing to the great weight of the wheel it was just warm when the test was completed. At any time during the test we could easily cause the engine to shut down due to overloading. Altogether the test was very satisfactory and our first test through the generator was found approximately correct.

In these two tests the cost of material was only trifling, the work was interesting and the results obtained were sufficiently accurate for our purpose.

THE GRADUATES IN PITTSBURG

The annual meeting of the University of Toronto Club of Pittsburg was held at the Fort Pitt Hotel on Thursday, January 4th, 1912. Mr. A. R. Raymer, '84, gave an interesting talk on the new Beaver Bridge, built by the McClintic-Marshall Construction Co., for the P. & L. E. R. R., over the Ohio River at Beaver, Pa. This bridge, involving the most modern principles of cantilever construction, formed a very interesting subject.

The structure consists of a main span of 769 feet, with 320-foot anchor arms and a 370-foot approach span. The trusses are 34 feet 6 ins. from centre to centre, accommodating four gauntleted tracks. The total weight of the structure is 18,000 tons. The work in both shop and field was done with such care that at the final closing the extreme points were within one-eighth of an inch, both horizontally and vertically, of the figured positions, and there was not a single back charge from the field to the office or shop.

The officers of the Club for the year 1912 include, president, Gardener Alison, '03; vice-president, H. O. Hill, '07, and secretary-treasurer M. L. Miller, '03, 206 Suburban Ave., Pittsburg, Pa.

WHAT OUR GRADUATES ARE DOING

This section is conducted with a double object in view: first to give the graduates professional news of each other; second, to give the undergraduates an idea of the possibles fields of employment open to them in the future.

F. W. Harrison, '05, is engaged as assistant to designing engineer, Brooklyn Edison Co., Brooklyn, N.Y.

Geo. E. Quance, '07, is secretary-treasurer of the enterprise Gas Co., Limited, and of the Delhi Light and Power Co., Limited, Delhi, Ont.

Chas. J. Murphy, '06, is chief engineer of the Crows' Nest Pass Coal Co., Fernie, B.C.

A. H. Arens, '06, is resident engineer for the Inverness Ry. & Coal Co., Inverness, N.S., in charge of mine surveying and mechanical drafting, etc.

J. A. Mackenzie, '06, and F. C. Broadfoot, '06, are engaged in engineering and contracting work in Vancouver, B.C., under the firm name of Mackenzie, Broadfoot and Johnston.

R. E. Pettingills, '06, is in Port Colborne, Ont., as chemist for the Canada Cement Co., Limited.

Wm. Snaith, '07, is secretary of the Canadian Cement and Concrete Association, and assistant engineer to Frank Barber, '06, York County engineer.

H. O. Hill, '07, of the Riter-Conley Manufacturing Co., Pittsburg, is at present in charge of the erection work of a six million cu. ft. capacity gas holder and foundations at Pittsburg.

APPLIED SCIENCE

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EDITORIAL

THE LECTURE ON SCIENTIFIC MANAGEMENT

The meeting of the Engineering Society on Friday, March 8th, was by far the most successful of the year, and members of the staff whose close adherence to the Society has extended through many years, have termed it the most important meeting the Society has ever held. The speaker was impressed at the outset with the great interest taken in "Scientific Management" at the University of Toronto, suggested by an audience of well over 1,000. Among them were representatives of dozens of Toronto's industrial and manufacturing firms, an equally good representation of graduates, and a record turn-out of undergraduates. A number of students from other faculties were also in attendance, among whom were a few of the ladies in the political economy course.

As an indication of the speaker's ability to accelerate and maintain the interest shown, it is but necessary to observe that at the end of two hours, a smaller part of which was occupied in discussion, the attention of his audience was so completely held that the adjournment seemed premature. A motion to adjourn, invariably producing the customary observation of the hour, does not often create surprise as it did at the conclusion of Mr. Gilbreth's lecture. The speaker did not adhere to his paper throughout, as it appears in this issue, but relapsed, oftentimes, into necessary elementary explanations for the students' benefit. These, supplemented by the paper as it appears, form a most valuable forerunner to a study of the subject and increase materially the value of the afternoon's investigations to all interested.

Directly after the meeting the executive entertained the speaker, together with a few members of the staff, at a little informal dinner at the Engineers' Club. It is regrettable that the entire audience of the afternoon could not have received the benefit of the discussion which accompanied the affair. The great scope of the subject was broadened time after time by our guest narrating experiences gained in his twenty-eight years of study and investigation. For instance, Mr. Gilbreth is at present deeply occupied in the study of its application to surgery, and his brief stay in this city was largely taken up by visits to our hospitals, to witness surgical operations. He is interested in the scientific arrangement of instruments, utensils, etc., around the operating table, with a view to improvement that will be life-saving in its effect perhaps, and, at least, less nerve-straining upon attendants. In several American cities the object of his endeavours is being embraced by the medical professions as the beginning of an enormous aid to the science.

Mr. Gilbreth, in the presence of a number of the members of the staff, strongly advised the study of "Scientific Management" as part of the curriculum in the Faculty of Applied Science, pointing out that one of the most valuable assets that a graduate can have is the habit of doing promptly, and to the best of his ability, the work set before him. With this habit and reasonable intelligence, he can make good progress. Combining with this the advantages of one of our courses in engineering, there is every chance of advancement, but, in Mr. Gilbreth's opinion, the habits of industry upon which success is contingent should be scientifically studied in every technical institution from the industrial school to the university.

TWELVE ISSUES PER YEAR

The February issue of *Applied Science* announced that it proposed to extend its publications to just twice as many issues per year. Having met with favor from all sources, the work will be undertaken. Most encouraging have been the opinions of graduates on the matter. These letters assure the journal of their support.

As a part of its new undertaking, *Applied Science* will double its efforts to bring closer together the undergraduate with the engineering profession, on the other hand, and the graduate with the University, on the other. This is in the best interests of all concerned, and, while the co-operation from every side is solicited, the "School" man, whether student or alumnus, is looked upon to consider this publication something more than the up-to-date engineering journal it hopes to become. *Applied Science* must be, to him, a journal with his interest always before it, as ready to receive his criticism as his approval.

MONTREAL GRADUATES GATHER

On Thursday, February 16th, the graduates of the Faculty of Applied Science of Toronto University resident in Montreal held a dinner at Cooper's Restaurant, and appointed officers for the ensuing year to arrange for other meetings of a similar nature. For a number of years this scheme has often been agitated, but the present occasion is the first instance that the question has been brought to a successful issue. A temporary committee undertook the arrangements and the hearty response was an emphatic indication of the popularity of the movement.

About thirty-five assembled and Mr. G. H. Duggan, general manager of the Dominion Bridge Company, the senior graduate of the evening, acted as chairman. With him were seated Walter J. Francis, H. Rolph, D. C. Tennant, J. A. DeCew and Alan S. MacDougall.

After the king's health had been drunk, and our own dean remembered in the same manner, a permanent organization was effected with the following officers:

President—G. H. Duggan.
Vice-President—W. D. Black.
Secretary-treasurer—H. W. Fairlie.
Entertainment Committee—J. A. DeCew, L. R. Wilson, W. D. Black, H. W. Fairlie.

The nominations and "suggestions" were interspersed with many memories of days spent in the "best school of all" while DeCew and Tennant thrashed to a satisfactory decision that Billy Grant was the real author of "Toike Oike." This was a question beyond Rolph's depth, and before he could be "shown," the now famous rallying cry had to be written out and the spelling all elucidated.

DeCew's abilities as a raconteur were greatly relished in his descriptions of the days when deep-seated was the belief that

"None but the righteous shall be saved"

with drafting board and tee-square accompaniment. However, his memories rather tended to show that some of the senior men—yes, some of those present—were no improved addition to later generations.

Afterwards a very pleasant social hour was spent in the renewa of old acquaintances, as well as in the making of many new ones, for the senior men lead by Francis, Duggan and Rolph, proved themselves the best of mixers.

"Dolly" Black, showing all the good effects of a benedict's life, did much to make the evening a success. Dundass, who has lost much of that "Monday-the-last-date-to-accept-lab.-reports" expression, led the bridge contingent, whose presence was a guarantee of the evening's success.

A number of our most prominent graduates were unable to be present, among them were R. A. Ross, J. M. Robertson, J. M. R. Fairbairn, N. M. Lash and H. V. Haighte. However, all sent messages voicing their enthusiasm in the movement, and expressing their best wishes for its success.

It is the intention of the committee to hold these gatherings at frequent intervals, and to all "School" men in Montreal and vicinity a hearty invitation is extended. It is hoped that every graduate in the district will ally himself with this association and help make it a strong factor in the university graduate life of Montreal. In Pittsburg and other centres organizations of this nature have already proved their popularity with the men who still look back with pleasure to the days when

"The 'School' could lick them all"

and there is no reason why the Montreal men cannot share in the same success in their undertaking.

THE ELECTRICAL CLUB

The Electrical Club excursion to Peterboro was most successful. The object of the excursion was to visit the works of the Canadian General Electric Co., which are situated there. Representatives of the company were at the station to meet the train and provided street cars to take the visitors to the hotel. Here, as guests of the company, a first-class dinner was provided and full justice was done to it. After dinner the works were visited, and with several of the company's engineers in charge of the various parties a most profitable time was spent in the various departments of this large works.

Several large generators similar to those installed by this company at Niagara Falls were in the course of construction and were of great interest to the visitors. It was also interesting to notice the large amount of apparatus and machinery in course of construction for the Western provinces.

The engineers who acted as guides were painstaking in answering the many questions which were asked and explained the various processes and machines so thoroughly and willingly that the visit to every department was of great interest and value to all.

One of the most pleasant features of the visit was in meeting a number of School men who are at present employed by this company.

About half of the men had to return to Toronto on the train leaving Peterboro at 4.28 p.m. and cars were provided to take them to the station. A number of the men remained over Saturday and visited several power plants of interest, including the Auburn Power Co., the city pumping plant and the power plant of the Canadian General Electric Co.

Professors Angus and Rosebrugh accompanied the Club, making a party of about forty-five.

At the regular meeting of the Electrical Club last Thursday evening, Mr. J. M. Barr gave a paper on the city waterworks system. Mr. Barr is a graduate of Glasgow University, and assistant engineer in the waterworks department.

The speaker first gave an excellent outline of the complete system showing the functions of the various pumping plants situated on the Island and in the city.

The remainder of the paper dealt with the several types of pumps in use. Mr. Barr described, at considerable length, the operation, construction and relative advantages of the two types of steam plunger pumps in use at the John Street plant. The steam pumps in the old plant are horizontal cross compound while the new pumps are vertical triple-expansion with an over-all height of fifty feet. It was pointed out that these new pumps are among the most efficient in existence. There are two of them in operation at the John Street plant, each having a capacity of 15,000,000 gallons in twenty-four hours. The old pumps have a capacity of 10,000,000 gallons in twenty-four hours. The High Level Pumping Plant also has two of the new steam pumps, but they are smaller than those at John Street.

The speaker also described the steam fire pumps which are at the lower station. These pumps are of the turbine type driven by steam turbines, and are capable of maintaining a pressure of 300 pounds in the high pressure fire system.

An interesting description was given of the new turbine pumps which have been installed at the various stations and are operated by hydro-electric power.

The city is well equipped with the means for pumping water, but is beginning to feel the need of more mains to distribute the water throughout the city.

Mr. Barr's paper was greatly appreciated by all who were fortunate enough to be present at the meeting, and a hearty vote of thanks was extended to him.

Professor Angus, who has tested all of the new steam pumps for the city, made a few interesting and instructive remarks regarding them. Mr. Randall, superintendent of the waterworks system, was also present and spoke a few words. A very instructive outline of the performance of turbine pumps was given by Mr. Allen, representative of the John McDougall Co.

TITLES OF THESES, DEPARTMENT OF ARCHITECTURE

J. H. Craig—Design of Legislative Buildings for a Canadian Province.
H. H. Madill—Design of Parliament Buildings.
H. Pullan—Design for a Synagogue.
E. V. Reid—A Terminal Railway Station.
P. Sheard—Design for Theatre.

WHAT OUR GRADUATES ARE DOING

C. B. Jackson, '07, is employed by the C. Everett Clock Co., of Kenilworth, Ill., as chief engineer and head of estimating department.

E. R. Smithrim, '07, is superintendent of the Watrous Electric Light, Power & Traction Co., Limited, Watrous, Sask.

D. J. McGugan, '07, is engaged in engineering work and surveying for the firm of Hill & Burnett, New Westminster, B.C.

G. H. Broughton, '07, is manager of the People's Trust Co., Limited, Penticton, B.C.

W. G. McGeorge, '08, is carrying on a general engineering and surveying practice at Chatham, Ont.

S. B. Osler, '08, is in charge of high tension pole line work and sub-station work with the Midland Construction Co., for Smith Kerry & Chace.

H. C. Doorly, '08, is assistant engineer for the Jenckes Machine Co., Limited, St. Catharines, Ont.

N. G. Madge, '08, is chief chemist for the Continental Rubber Co., of New York.

J. St. Lawrence, '08, is superintendent of the engine shops for the Erie City Iron Works, Erie, Pa.

C. N. Danks, '09, is in the engineering department of the Canadian Rand Company, Limited, engaged in the design of air compressors and hoisting engines.

D. S. Stayner, '09, is engaged in the city engineer's office, Toronto, in the department of railways, bridges, and docks, as resident engineer on Ashbridge's Bay docks.

C. A. Morris, '09, is mine surveyor for the Canadian Copper Co. at Copper Cliff, Ont.

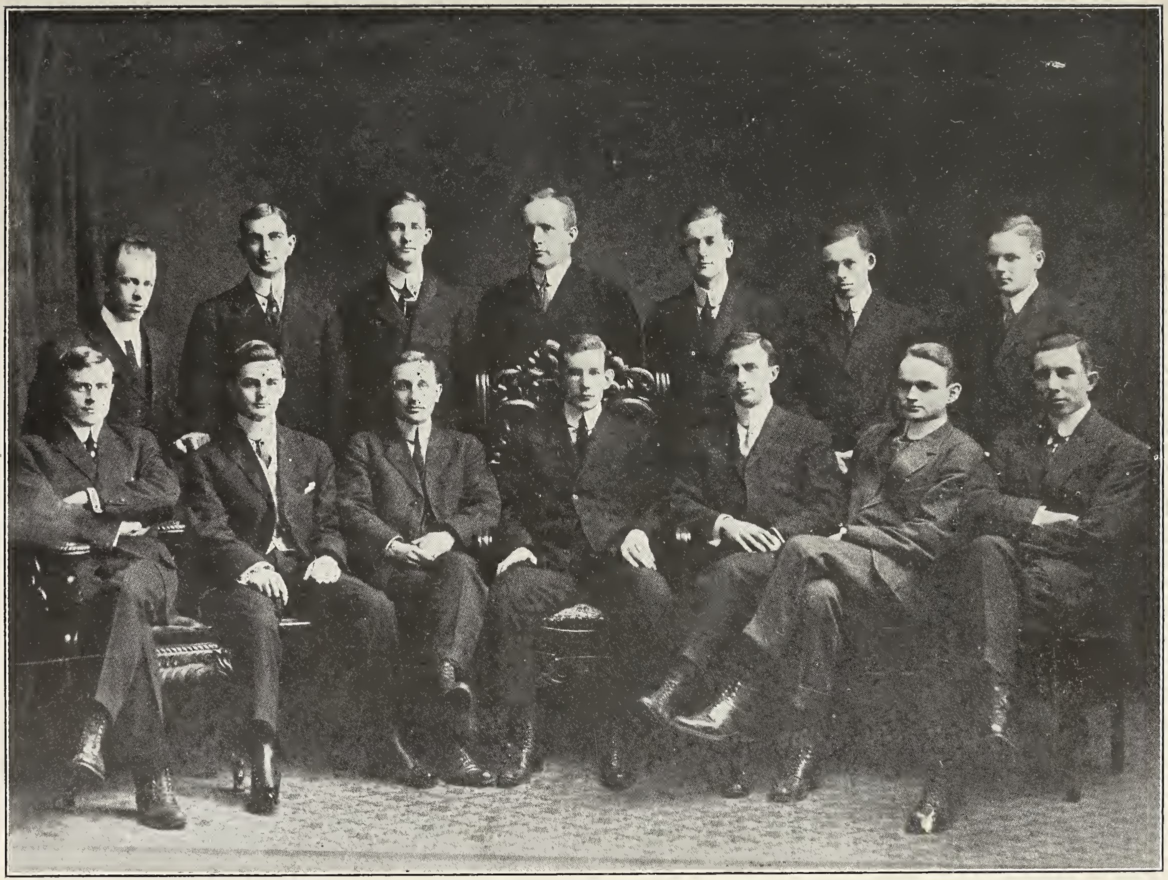
J. E. Underwood, '09, has recently become a member of the firm of McArthur & Murphy, consulting engineers, Saskatoon, Sask.

J. A. Baird, '10, is with Alexander Baird, O.L.S., as assistant land surveying and municipal drainage and reclamation work, also bridge construction in Western Ontario.

W. S. Mackenzie, '11, is with the Canadian Linderman Co., of Woodstock, as tester and installer of woodworking machinery.

L. W. Rothery, '11, is superintendent of construction for the Tri-State Railway & Electric Co., East Liverpool, Ohio.

F. H. Downing, '11, is erecting engineer for the Manitoba Bridge & Iron Works, and at present in charge of the erection of transmission equipment in the National Transcontinental Railway shops near Winnipeg.



THE ENGINEERING SOCIETY EXECUTIVE, 1911-12

Top row—A. A. McQueen (Corr. Secretary), F. G. Matthews, H. O. Heaton, F. C. Mechin, R. F. B. Wood, W. G. T. Wright, R. D. Galbraith
Bottom row—H. Irwin, B.A.Sc. (Gen. Secretary), J. E. Ritchie (Vice-Pres.), R. J. Fuller (1st Vice-Pres.), W. B. McPherson (President), C. F. Elliott (Treas.), K. S. Maclachlan (Vice-Pres.), G. J. Mickler, (Vice-Pres.)

APPLIED SCIENCE BOARD, 1911-12

Top row—R. J. Fuller, W. B. McPherson, R. J. Mickler, K. S. Maclachlan, J. E. Ritchie, C. F. Elliott
Bottom row—S. Dushman, Ph.D., H. E. T. Haultain, C.E., H. Irwin, B.A.Sc., H. W. Price, B.A.Sc., C. R. Young, B.A.Sc.

Applied Science

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF
TORONTO ENGINEERING SOCIETY

Old Series Vol. 24 APRIL, 1912 New Series Vol. V, No. 6

RETIRING ADDRESS OF THE PRESIDENT

Gentlemen:—It is the custom that the president deliver an address at the close of his term of office. This is my lot to-day, and in reviewing, to some extent, the work done during the past year, I wish to point out the great deal of attention that has been directed throughout the past months to "Getting in Touch with Graduates" and "Spreading the Name of the School Abroad."

When we mapped out the term's work it was decided to bring to our meetings speakers who could tell our members something on new phases of engineering.

The November meeting was addressed by Mr. E. H. Darling, of Hamilton, who gave an excellent paper on "Preliminary Problems in the Design of Manufacturing Buildings." At the next meeting Professor A. G. Christie, of Wisconsin, spoke, his subject being "Steam Condensing Equipment." Mr. W. H. Boyd, of Ottawa, presented a most instructive paper in February, on topographical work in connection with the Dominion Geological Survey Department. At the meeting on "Scientific Management" as addressed by Mr. Frank B. Gilbreth, of New York, we were rewarded by a record breaking attendance, well exceeding a thousand. Of those present at least two hundred were not graduates of, or students in, the Faculty of Applied Science. The last general meeting did not receive the usual large attendance, owing to press of work at the close of the term. Mr. Rudolph Hering's paper on "Sewage Purification" was a splendid treatment of this department of the great subject of sanitation.

The sectional meetings have been none the less important. The civil and architectural sections have received papers by Mr. C. R. Young, on the two great English engineers, Brindley and Smeaton; Mr. P. H. Campbell, on "Tubes of Brooklyn and Manhattan"; Mr. E. R. Gray, on "Trunk Sewer Design and Construction"; and Mr. H. J. Glaubitz, London, who spoke on the installation of a new system of water supply for that city. Mr. Frank Barber also addressed this section on " Concrete Bridges."

The electricals and mechanicals heard Mr. H. P. Dwight, of Hamilton, who spoke on the effect of "Double Voltages"; Prof. H. W. Price, on "Lightning, Lightning-Arresters and Line Surges"; and Mr. F. H. Moody, on "Mallet Locomotives for the C.P.R."

The miners and chemists were addressed by Mr. A. Neighorn;

and Mr. T. D. Robertson, who gave a paper on "Recent Developments in Electrical Iron Smelting."

Extremely good attendance has marked sectional as well as general meetings. The new orchestra, ably conducted by Mr. Temple, has done much to make the meetings more enjoyable, and the men connected with our new organization are to be heartily thanked for the time and work they have given during the year.

Turning to the Supply Department, which your vice-president, Mr. Fuller, has reported on, a strenuous effort has been made to have all supplies likely to be needed on hand, in large enough quantities to prevent annoying delays. Prices are kept as low as possible, and on the whole there is a saving of nearly thirty per cent. to the students on their purchases over ordinary retail prices. An accurate check is kept on all funds and stock, and the department is run on strictly business lines. The published notes and textbooks by the members of our staff are being added to constantly, and a book on Mechanics of Machinery by Prof. Angus is added this week.

The Retiring President: Wm. Batten McPherson

Applied Science, under its able editor, Mr. Irwin, is doing splendid work, and is binding the graduates more closely to their School. Throughout the year letters of a very complimentary nature have been received from all over the continent. Your executive has decided to publish from now on twelve issues of the magazine per year, instead of six as formerly. It is felt that a much wider and more useful scope can be met. The outlay required to do this will not amount to much. The subscription price to graduates and undergraduates will remain unchanged, and it is hoped that each will receive the summer issues as regularly as those of the college term.

The twenty-third annual dinner on January 18th was a success as a dinner, but not as an undergraduate function. We placed in the hands of each student an invitation and a letter explaining what the dinner really was. Much work was done in an endeavor to interest the boys, but unsuccessfully. The graduates turned out well. Many of them had not been back to the School for years. This dinner fills a very important place in our year, and the expense is not heavy enough to bother the students at large. The Commission of Conservation were our guests, and while only a small number of the members were present, we had personal letters from every province of the Dominion from prominent men who are members of the Commission, expressing interest in the work of the University of Toronto, and in our faculty particularly.

The School dance on February 9th was attended so well that the capacity of the "Old Gym" was severely taxed. The complete sixty foot model of the new Quebec Bridge, which formed a central part of the decorations, caused much surprise and commendation. This function stands out very prominently in the social life of the University.

This year has seen an important change in the curriculum. I refer to Christmas examinations. The step had been talked of for some years and your thanks are due to our predecessors for the change. The pay boxes were withdrawn from the telephones, thereby removing a popular old election plank. Smoking rooms, so often dreamed of, are entirely out of question because of the very cramped condition of the buildings. A filing system has been installed to place business on as complete a basis as possible, and records of this year's work on the file will serve as a help and guide to the new executive. A large number of factories and industrial institutions were communicated with during the year, and they all signified a willingness to give our members every opportunity of visiting them. Many of these opportunities were taken advantage of, and several large parties also made trips during the autumn term to places of interest both in and out of Toronto. The excursion to the Ontario Power Company's plant at Niagara Falls was especially enjoyable, and the same applies to the excursion to Lackawanna, N.Y.

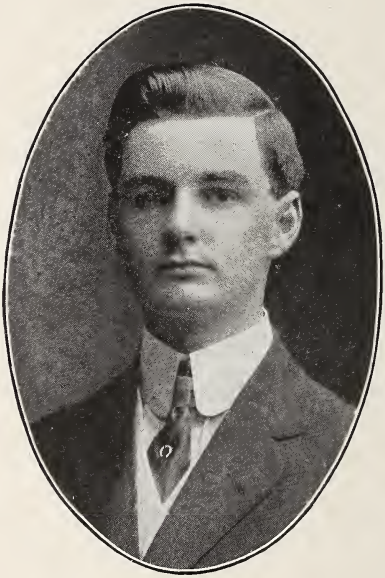
Your thanks are due to the faculty for the deep interest taken by them in this Society, and particularly to the Dean, Professor Wright and Mr. Cockburn, for the aid and advice they have given your executive.

The library in the supply department has received the addition of a number of the best English periodicals, in addition to the other Canadian and American publications. New binders will be placed on all these journals before the end of the term. Space is limited, and the equipment is about as complete as possible at present.

The finances are in a very healthy condition, as shown by the treasurer's report.

The elections on March 15th were as lively as ever, voting taking place in both the afternoon and evening. Eighty per cent of the student body voted, which was most satisfactory. The election paper "Toike Oike," was published three times, with Mr. P. G. Cherry as a hard working editor-in-chief. His work deserves much praise.

It appears to me, after the experience of this term, that the students in the Faculty of Applied Science ought to take more interest in both the affairs of this University and our Faculty. A college course is only partially obtained in classes and lecture rooms, and there are few men here indeed who cannot afford to pay more attention to "getting acquainted with" their fellow students and shaking themselves to help their Alma Mater along. Our best graduates, the men who are doing most to **boost** the name of this institution are those who were active in their school days, both in and out of the lecture rooms. Our attendance is almost eight hundred, and every effort must be made to weld the men of "the school" into the solid family they have always been in the past. When you are away during this vacation keep the Engineering Society posted on the



The President-Elect; J. E. Ritchie

graduates you meet, and what you yourselves are doing. The best advertising an institution can have comes from the men who have been within its walls. Advertise your faculty and your University.

In conclusion let me thank the members of this Society, which is the School, for placing me in this office. You gave me a strong executive, one that worked hard and one with which work was enjoyable. It is impossible to speak too highly of them. During the year we have had the broadening of the Engineering Society constantly before us, and the new executive, with the experience its President has had on the executive during this year, will ensure much success during 1912-13.

I introduce your new president, Mr. J. E. Ritchie.

WM. BATTEN MCPHERSON.

The Regina Engineering Society has just completed organization, adopted a constitution, and elected an executive council. Mr. A. J. McPherson, '93, who was City Commissioner of Regina, and resigned on the 1st inst. to assume the chairmanship of the Highways Commission of the province, is president of the organization. Mr. H. S. Carpenter, a graduate of '97, now Deputy Minister of Public Works for the Province of Saskatchewan, is 1st vice-president. Mr. L. A. Thornton, City Engineer of Regina, and 2nd vice-president of the Engineering Society, is a graduate of Queen's University. The Society is holding an inaugural dinner on the evening of May 2nd.

WHAT OUR GRADUATES ARE DOING.

W. H. Martin, '10, recently on survey work in Edmonton, is with the Hamilton Bridge Works.

N. C. Sherman, '11, is Inspector of Ordnance Machinery at Esquimault, B.C.

H. P. Elliott, '96, has offices in the Manning Chambers, Toronto, as industrial engineer.

A. W. McConnell, '06, Department of Architecture, University of Toronto, and Mr. Stanley Makepeace, have formed a partnership to engage in architectural work, with offices in the Kent Building, Toronto.

W. F. Grant, '98, has resigned as city engineer for Sault Ste. Marie, Ont., and Mr. W. W. VanEvery, '99, assumes the position. The city has in view the construction of considerable new sidewalks and pavements, and sewerage works.

G. C. Parker, '10, is associate editor of "Motor" magazine, Saturday Night Building, Toronto.

W. A. Clement, '89, formerly city engineer of Vancouver, has been appointed chief engineer of South Vancouver.

F. T. Nichol, '10, is assistant engineer to Clarence W. Noble, Toronto.

SEWAGE PURIFICATION*

By Rudolph Hering, D.Sc.

The subject of sewage purification, on which you have asked me to talk to you to-day, found its first scientific and practical development in England during the latter half of the last century. The quantity of sewage to be dealt with in that rapidly growing country, increased so greatly that, more than elsewhere, it presented very serious conditions, both dangerous to health and productive of nuisances. Further, the rivers of England, into which the sewage of interior towns was first naturally discharged, are small, not only because of the small watersheds, but also because the rainfall upon most of the area is only about one-half of what it is near our Atlantic Coast. Objectionable results were, therefore, sooner felt than would otherwise have been the case.

The first material advance that gave satisfaction was the discovery between 1860 and 1870 that sewage, spread upon porous sandy material and allowed to percolate through the same intermittently at a rate equivalent to the sewage of 1,000 persons per acre, allowed a purification to take place so thoroughly that the effluent water was not only clear and non-odorous, but was deemed entirely healthful for fish life, and for cattle.

In the next decade, this method of purification was adopted for treating the sewage of Berlin and then of Paris, and is still employed successfully by both cities upon the large areas of sandy soil in their vicinity. About 1890 a very extensive series of experiments on a large scale made at Lawrence, Mass., confirmed the scientific basis for this method of sewage purification, which was the action of bacteria and other low forms of life, first suggested by Dr. Alex. Müller, City Chemist of Berlin, about 1880. Since then it has been applied in all civilized countries where suitable conditions were available.

It was not possible, however, to find, particularly in England, sufficient area of porous land for all or even for most of the cities. Some other means had to be devised, and a so-called chemical precipitation method came into use. By the addition of certain chemicals, such as lime, sulphate of alumina, etc., the sewage was clarified, and it was thought sufficiently purified to be turned into streams. This purification, although a material step of progress, was not real. The resulting precipitated suspended matter, forming what was called a sludge, was so objectionable on account of its offensiveness, and the clarified liquid which still contained putrescible matter again became so foul, that the method was only adopted where none other was available, and research was further continued.

Near the end of the last century, it was found, chiefly in two cities of the northwestern part of England, in Salford and Accrington, that in the absence of sandy soil, it was practicable to make sewage liquid non-putrescent on a large scale, by allowing it to percolate slowly through beds of stone, from one-half to three inches in diameter. This advance caused the adoption of so-called percolating or sprinkling filters, which, on account of their economy, are being extensively introduced.

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*Read before the University of Toronto Engineering Society, March 27th, 1912.

About the same time it was also found in England that, by leaving the sewage liquids repeatedly in contact with the stone surfaces in similar beds of stone, after they had become covered with bacterial slime, a like purification resulted, not only in the liquid but also of some of the solid matter. These so-called contact beds have also since been extensively adopted.

For nearly thirty years, and until quite recently, efforts have been made to find some means of overcoming also the other trouble, namely, the sludge nuisance resulting from the above methods of treating the liquids. The so-called septic tank was suggested in England about twenty years ago to solve the difficulty, as it had been found that the sludge under certain conditions would largely rot away, and therefore, leave a much smaller amount for final handling. But the anticipations as to the extent of the rotting away were not realized and the whole process was very offensive, leaving the question still surrounded with doubt as to a satisfactory treatment.

During the last decade, Dr. W. O. Travis, of Hampton, England, made a further advance by separating the suspended matter from the liquid more thoroughly than had heretofore been attempted, believing that the main trouble lay in the fine, suspended and colloidal matter. He used an upper and lower chamber for the sewage tanks. The sewage was to flow through the upper one and be retarded sufficiently so that the heavier suspended matter would drop through a horizontal slot and slide into the lower chamber for deposit and subsequent removal. It was deemed necessary by Dr. Travis, that while about four-fifths of the sewage should flow through the upper tank, about one-fifth should flow through the lower tank. While this separation had advantages, it was found that the sludge, when it was taken from the lower tank, still gave off an offensive odor.

Experiments were made with the Travis tanks in Essen, Germany, by Dr. K. Imhoff, beginning about 5 years ago, which proved that, by completely preventing a flow through the lower tank, a decomposition of the sludge could be made to take place in an inoffensive manner, and that the sludge, when withdrawn, after a few months had no longer an offensive odor. These same results have since been verified, not only in Germany, but also in the United States and England, so that this new and unexpected result, produced by the so-called Imhoff Tanks, has caused the subject of sewage purification to be viewed in a new and more encouraging light.

We can now say that, under conditions found in large as well as small cities, on sandy as well as clay soil, along small as well as great rivers, it is practicable to dispose of the sewage from inhabited territory without causing offensive conditions, either from its liquid or its solid matter.

It is my intention to briefly outline what to-day we consider to be the chief principles upon which this inoffensive sewage purification is based, and which enables us to design and operate works in a manner more satisfactory than was possible but a few years ago.

Sewage, Its Definition and Characteristics

At the outset it will be well to understand as clearly as practicable the conditions of the material with which we have to deal. Let us, therefore, realize that sewage is practically the dirty water resulting from the washing of our bodies and clothes, implements and articles of use, the floors of our habitations, and chiefly from the discharges from our bodies. Sometimes the rain water running off from the surface of the land, of city streets, roofs, etc., also forms a part of the sewage.

An analysis of this dirty water shows, on this side of the Atlantic, about one part of decomposable organic matter to 5,000 and even 10,000 parts of water. This, apparently great dilution does not, however, prevent a putrefaction of the sewage from taking place under favorable conditions with resulting foul odors.

The water which is used to receive and carry this dirt along in suspension, from the point of origin to the point of final disposal, is the usual water supply of a city. In some cities it is augmented by the rain water washings from the surface which combine with the sewage in what we call a combined system of sewerage. Where the rain water is prevented from mixing with the domestic sewage, and where it is taken away in separate drains, we speak of the separate system, which has substantially two independent net works of piping to dispose of these two waters in different ways and to different points of outfall.

The characteristics of sewage proper are quite complex. Let us first consider those which prevail within the first few hours of its existence.

In a separate system we have in the domestic sewers the sewage proper, and in the rain water drains the surface washings from the general city territory. Analysis and other studies indicate that in a city where the streets are not well cleaned, the first water entering the drains from a rain storm has a composition, which, so far as subsequent objectionable results are concerned, is not materially different from that of the sewage proper. For this reason the so-called combined systems, receiving both sewage and street water, particularly in large cities, have been favored and preferred for economical reasons, as they require but a single network of sewers and more simple management. The question as to the preference between separate and combined systems for any given city or for part of a city, must be carefully investigated and decided chiefly on economical grounds.

Domestic sewage is a carrier of disease germs and a carrier of the nonresistant organic matter which, within a few hours, may putrefy and cause a nuisance. The disease germs enter chiefly from the excretal discharges, and wash water of the body, and the laundry waters; in some cases also from the water used in cleaning implements and rooms. The putrescible matter enters also from kitchen waste water, food rests, dish washing and house cleaning, containing a large amount of matter which readily becomes putrescent.

Sewage may be divided into solids, colloidal suspensions and solutions. The solid and colloidal matters entering the sewage are carried along, and if the velocity of the sewage is sufficient they may be kept in suspension until the sewage is finally discharged.

Sewage does not remain long in the condition in which it enters the sewers. Changes take place in different ways. The matters in solution are at first limited to very few sources, the chief of which are urine, mineral salts, and a few nitrogenous compounds. As sewage flows along the dissolved matter, however, increases rapidly so that analysis in fairly good sized cities show that about half the organic matters of sewage are in solution, while the other half are in suspension. The matter in suspension includes also what is usually called colloidal matter, and that which is in the state of emulsion, consisting chiefly of nitrogenous substances of more or less complex character as soap, fat, some cellulose, etc.

When the velocity of the sewage changes, the heavier suspended matter deposits and some is attracted by the sides of the sewer, both remaining until the velocity is again increased to wash this retained matter away. While it is in a state of retention a change is apt to take place through bacterial action, as will presently be mentioned.

While the sewage is flowing along, the dissolved matter, as already stated, is increased in quantity, and that part of the suspended matter which is most easily reduced, is converted by bacterial action, into liquids and gases.

Another class of changes may take place, if sufficient time elapses by long retention, as a coagulation of some of the colloidal and dissolved matters on the one hand, and on the other a de-solution of dissolved matter by its conversion into colloidal matter. The latter phenomena are chiefly the result of the life of bacteria and of the forming of the bodies of other small organic life, inhabiting the sewage or the slimy matter attached to the material adjoining which sewage flows.

An important factor further is the temperature at which the decomposition of putrescible matter takes place. There is an optimum temperature at which the decomposition is most rapid, because it is the best for the life of the bacteria and insects which cause it. Unfortunately, it is rarely possible to control the temperature of sewage to any extent, and, therefore, to make use of the best temperature.

Finally, it should be stated that the main causes of change in sewage originate mostly in the excretal discharges and such waste matter which has allowed of bacterial development before entrance into the sewers. The decomposition which takes place at first causes a seizure upon the oxygen dissolved in the water and upon that which is available from the decomposition of some of the matter contained in the sewage. So long as such oxidation can take place the sewage is not offensive. As soon as the oxygen is exhausted other processes begin; a so-called anaerobic decomposition takes place, creating hydrogen and carbon compounds, and when the sewage is exposed to certain classes of bacteria, putrefaction and offensive gases result, constituting the cause of the foul smells which we observe from sewage.

Fundamental Requirements for Sewage Disposal

The chief requirements which the engineer has to satisfy in devising works for sewage disposal, can be divided into two classes, the first relating to the destruction of disease germs, and the second to the prevention of nuisances.

The destruction of disease germs may be accomplished in two ways, namely, by starvation or by disinfection. Starvation means the creation of conditions by which the environment causes the disease germs to perish from lack of suitable nutriment or conditions of life. Disinfection is produced by the addition of some matter poisonous to the bacteria which causes them to be disintegrated or the conditions for their life eliminated.

The other fundamental requirement for sewage disposal is the prevention of nuisances. As nuisances are caused by the putrefaction of sewage, we first conclude that if sewage is sufficiently diluted and exposed to a sufficient amount of oxygen, then there will be a process of oxidation instead of putrefaction, and no offensive conditions result. The necessary amount of oxygen can be obtained from the air and from water, when the conditions in each case are favorable.

In the absence of the necessary amount of oxygen the decomposition of sewage matter may be offensive or it may not be so, depending upon the organisms which effect the decomposition. Much is yet to be learned regarding these organisms, but at the present time practical experience has developed sufficiently, so that in most cases it is practicable to foretell whether the decomposition will be offensive or not.

To prevent a nuisance in the decomposition of sewage matter we must satisfy three conditions: First, we must separate the liquids from the solids, then we must oxidize the liquids, and thirdly, we must effect a satisfactory decomposition of the sludge. By separating liquids and solids we are enabled to treat each part by itself, according to the ways and means best adapted to each case, because the best method of treating liquids is generally different from the best method of treating solids.

In dividing the sewage into liquids and solids we must realize that, strictly speaking, the division is not correct. What we call liquid in this case includes a large amount of fine and suspended colloidal matter which will not readily separate from the true liquid and deposit. As will be seen presently, this fine colloidal matter is best treated together with the liquids and not with the solids.

The oxidation of the liquids, as thus defined, will take place by having a sufficient amount of air brought in contact with them. It would lead too far to go into the details of the oxidation process, and it must suffice to state here that unless a sufficient amount of air is brought in contact with the liquid, putrefaction may take place.

The decomposition of the suspended matter after it has settled out as sludge, cannot be accomplished by oxidation, because there is no way of bringing a sufficient amount of oxygen into contact with every part of the sludge. It is possible in a dry climate to effect a decomposition of dead putrescible organic matter through eremacausis by an exposure to sunlight and air, without offensive results. But it cannot be done in our climate, and means other than oxidation must be used.

PRACTICAL METHODS OF SEWAGE DISPOSAL

After having defined sewage and stated the chief requirements for sewage disposal, it now remains to discuss the practical methods by which such a disposal may be secured.

Let us first consider the case when the sewage must be treated entirely on land.

Treatment of Sewage on Land

As stated at the outset, the object of treatment is to destroy the disease germs which may be in the sewage, and to prevent a nuisance during the process of changing the raw sewage into water and non-offensive sludge.

In order to accomplish this result most effectively and most economically, it is necessary to deliver the sewage to the place of treatment as fresh as possible, and still retaining oxygen in solution, which with good sewer construction and good flushing is nearly always practicable.

The second condition is to substantially separate the liquid and the solid matters. This is partly accomplished, first, by the introduction of screens which will keep out the grosser floating matters and allow them to be separately dealt with. These screenings do not necessarily cause trouble as they constitute a comparatively small part of the sewage and can readily be buried or burned.

The next process is the separation of the heavier suspended matter by deposition. To accomplish this it is necessary to reduce the velocity of the sewage to a very slight one, so that the sewage may be retained from one to three hours, according to circumstances, during which a sufficient deposition may be effected.

The result will be that the clarified sewage can run off without having been retained sufficiently long to have exhausted the oxygen dissolved in the sewage, and, therefore, not sufficiently long to have become septic and foul smelling.

The subsiding suspended matter should slide through a horizontal slot into a lower chamber for final decomposition, and in such a manner that it will not rise again to mix with the fresh sewage. Such conditions are provided by the Imhoff tanks, the only process known at the present time, which simply and rapidly produces an inoffensive sludge, preserves the fresh condition of the sewage, and at the same time reduces the sludge quantity by decomposition to about ten per cent. of the amount originally depositing in the lower chamber.

The only explanation of the inoffensive decomposition in the Imhoff tanks so far suggested is, that the prevention of any flow through the lower chamber precludes a continuously added large supply of the many species of bacteria which accompany sewage. The result is a gradual extermination and elimination of most of the various classes of bacteria, fortunately leaving only those which produce methane, hydrogen, nitrogen and carbon dioxide gases, none of which are offensive. The bulk of the escaping gases are 75% methane and 25% carbon dioxide. If we remove some of the sludge from the lower chamber before it is sufficiently decomposed or the putrescible matter entirely rotted away, and expose it to the air for some time, then offensive gases will soon be evolved, showing that in the lower chamber, where the sludge is confined, a different bacterial condition prevails from that where the sludge is exposed either to fresh sewage or to the atmosphere.

To cause the decomposition to be as rapid as possible, it is necessary to have as much movement of the sludge particles as possible, which dissipates the resulting products of decomposition and exposes new surfaces to bacterial attack. The movement is accomplished chiefly by the gas bubbles rising through the deep mass of sludge, and also whenever advisable, by introducing clean water through perforated pipes at the bottom. The introduction of this water also loosens the sludge near the bottom and facilitates its final withdrawal.

According to the nature of the sewage and climate it has been found that sludge will not rot sufficiently to be inoffensive in from two to five months. When it is withdrawn it has a slight odor of tar, which, however, can be perceived only a few inches distant. It is filled with bubbles of compressed gases due to the fact that the sludge has been compacted under a water pressure usually ranging from 20 to 30 feet. On the release of this pressure the sludge therefore begins to expand, like rising dough, and therefore becomes quite porous. This porosity allows the water, which is still contained therein, to drain out, with the result that the sludge, if spread upon under-drained beds, can be dried within a week's time so as to be spadable and removed. No offence is connected with the sludge discharge and removal and the water draining from it is quite inoffensive and generally clear.

The sewage after passing through the upper chamber of the tank, if it must be further purified on land, is treated by a process of oxidation, and if necessary, subsequently by a process of disinfection. It is practicable to oxidize the liquids, as already stated, by intermittent filtration through beds of sand, by so-called percolating or sprinkling filters, and by so-called contact beds.

In the first case, when the liquids flow upon sand beds, we may abandon the preliminary deposition of sludge and permit it to be deposited upon the surface of the sand bed, where it may be so thoroughly exposed to the air that putrefaction can be prevented, and an inoffensive decomposition by oxidation substituted. The oxidation of the liquid, percolating through the sand over a very large surface of bacterial slime which covers the grains of sand is very thorough and sometimes produces an effluent equal to that of spring water.

In the second case, the oxidation is produced by a percolation of the liquid, spread out in drops like rain over the surface of a bed of broken stone at least 6 ft. in depth. The spreading out is done either from fixed jets or from traveling distributers, either rotary or parallel, which distribute the sewage drops over the surface of the bed. While percolating over the surfaces of the stones, which vary in size according to different plants from half inch to three or four inches in diameter, the air circulating through the interstices makes the rapid oxidation possible. When the liquid issues at the bottom of such works, when they have been properly designed and after sufficient time has been given for the percolation, it is nonputrescent. The purification has been accomplished partly by bacteria living within the slimy coating surrounding the stones and partly by other lower forms of life inhabiting the interstices.

When the coarse grained filters permit the growth of myriads of insects and plants, transforming the dissolved matter into the colloidal matter of their bodies, then the remains of this life in a well proportioned and operated filter constitute chiefly the so-called humus, which is washed out of the filter, when both temperature and increased flow are favorable for its detachment and removal. Where the discharge of such humus into the receiving water course is objectionable, a second settling basin is usually interposed to allow of its deposit therein. This second basin can be utilized also for a disinfection of the effluent, should it be required.

In the third case, the oxidization is produced by a sufficiently long contact of the sewage with the grains of material forming contact beds. In order to have a sufficiently large slimy bacterial surface for the oxidation and an opportunity for the dissolved organic matter to come into contact with it, these contact beds must be made of much finer grained material than percolating beds. Therefore, they eventually fill up by clogging and require cleaning or replacing. The oxidation takes place substantially upon the bacterial surface after the sewage, except that which adheres to the grains, has been withdrawn. After a sufficient oxidation has taken place the bed is again filled with sewage to wet the grains. The same sewage requires to pass two or three times through such a contact bed before it is sufficiently freed from its sewage matter to become nonputrescent. One to three doses a day have thus been treated.

If it is necessary in these three cases to disinfect the liquid issuing from the beds, some chemical, generally hypochlorite of lime, can be applied to the effluent, which has been practically relieved of its suspended matter, and can, therefore, be disinfected quite economically.

Treatment of Sewage by Dilution in Large Bodies of Water

Where large bodies of flowing water are available, and practically saturated with dissolved oxygen, it is possible to effect the oxidation of sewage liquids by mixing them with such water. The oxidation in this case is not as rapid as when the oxygen is derived from the air, because of the smaller amount of oxygen contained therein.

Experience has shown that in order to oxidize sewage by running water it is necessary, depending upon the character of the sewage and the flow in the water course, to have an available flow of from two to six cubic feet per second of water, saturated with oxygen, to purify the sewage from 1,000 persons. Where this amount of water and oxygen are not available it is not possible to effect a satisfactory purification by dilution.

It is often practicable, however, to precede the dilution by a preliminary treatment to a degree to still enable the diluting water to accomplish the remaining purification.

If we consider the destruction of disease germs, this can be effected in a case of dilution, either by allowing the germs gradually to starve from the lack of suitable conditions for their life, or by their destruction through disinfection. That sewage bacteria rapidly perish, after entering a stream of clean and well oxygenated water, is in evidence wherever such conditions exist. Disinfection can be accomplished by adding hypochlorite of lime sufficiently far up the sewer before it discharges, so as to become thoroughly mingled with the flowing sewage. In Europe this disinfection has been practised for a number of years in a number of cities before discharging their sewage into rivers.

Where we desire to prevent a nuisance, the first treatment should be a screening out of the floating matter. This will prevent the visible evidence of sewage nuisance. Then, if the river or stream has sufficient quantity of water and contains sufficient oxygen to oxidize the screened sewage, it should be discharged into this body of water in such a manner that the sewage is thoroughly dispersed and brought as rapidly as possible in contact with the oxygen available. This dispersion is best effected at the bottom of the river and across the current.

When the flowing water is neither sufficient in quantity, nor has a sufficient velocity to carry the easily putrescible organic matter in suspension until it is oxidized, it will then be necessary to pass the sewage through settling tanks before entering the river. In these tanks this suspended matter can settle into a lower chamber, as already described, and decompose sufficiently so that, when removed after several months, it will be inoffensive and can be taken to final places of disposal without objection.

We have now hurriedly passed over the field which has become available to the engineer for disposing of the sewage from cities without any offence under all usual conditions.

To recapitulate, if the sewers are kept clean and flushed so that the sewage remains fresh, no putrefaction should result within them and the sewage can be delivered at the disposal works before it is offensive. This result is accomplished in many instances. If we then separate the liquids from the sludge in a thorough manner, the liquids will remain fresh and the sludge can gradually and inoffensively decompose and be converted into a material resembling forest soil, to be disposed of in any desirable way without objection.

If the liquid sewage, after being freed from the sludge, requires further purification, it is practicable to oxidize it without offence either on sand filters, in percolating beds or in contact beds, which ever may best suit the local conditions.

All of these stages of sewage treatment can now be accomplished without serious difficulties, with an assurance of success and at a reasonable cost.

THE ARMY OF GOD KNOWS WHERE

No bands are playing gaily when they're going into action,
No crowds are cheering madly at their deeds of derring-do;
They are owing small allegiance to any flag or faction—
Their colors on the skyline and their war-cry, "Put it through!"

Ahead of both the Bible and of late repeating rifle,
The flags can only follow to the starting of their trail;
They heard the leagues behind them, every mile the merest trifle;
They mark the paths of safety for the slower sail and rail.

Their standards kiss the breezes from the Arctic's cooling ices
To where the South Pole's poking out its late discovered head;
You can see their chains a-snaking through the lands of rum and spices—
And East and West you'll always find their unrepining dead.

No time for love and laughter, with their rods upon their shoulders,
No time to think with vain regret of home or passing friends.
They are slipping down the chasms, charging up the mighty boulders,
The compass stops from overwork; the pathway never ends.

They slit the gullet of the earth; disgorge its hoarded riches
(But life's too short for them to stop and snatch a rightful share);
They've a booking on the Congo putting in some water ditches;
A dating to take tea with death; they make it by a hair!

You will find their pickets watching in the unexpected places;
You will hear them talking freely of The-Things-That-Can't-Be-Done;
Oh, the Faith they speak so strongly and the Hope that's in their faces—
It lights the gloom of What's-the-Use as brightly as the sun!

No bands are playing gaily and no crowds are madly cheering;
No telegraph behind them tells their deeds of derring-do;
But forward goes the legion, never doubting, never fearing—
Their colors on the sky-line and their war cry, "Put it through!"

(Dedicated to Our Civil Engineers)

THE INDUSTRIAL CHEMICAL CLUB
Top row—G. L. Gooderham, W. D. Morris, G. E. Clarkson
Bottom row—A. R. Bonham (Treas.), E. R. Williams (President), A. W. Sime (Sec.)

THE YOUNG ENGINEER AND THE TECHNICAL SOCIETIES

By C. R. Young, A. M. Can. Soc. C.E.

Experience has shown that it is not good for man to be alone in a professional any more than in a domestic sense. The engineer who confines himself strictly to his own interests not only limits his usefulness to his own profession and to the community at large, but at the same time defeats his own personal ambition. Minding one's business is commendable, but it may be overdone. The names of those who mind other people's business, and do it well, are written largest in the history of every country. The engineer, perhaps more than anyone else, needs to appreciate this. His forced independence and tendency to absorption in narrow and non-popular specialties lead strongly to isolation, even from engineers engaged in other fields—a condition to be avoided at all costs. Alone his strength is merely his own, but in co-operation with his fellow-engineers, he in a certain measure commands the resources of all.

Almost as soon as engineers began to have any existence at all as a body, the need of union and co-operation was felt. Like most primitive desires, this was chiefly for personal improvement and advancement. The young English-speaking engineer in the time of Brindley, Smeaton or Telford, could not obtain the fundamental training for his profession in a technical college, for such institutions did not exist. Outside of what, he himself discovered by experience as an apprentice or as an independent practitioner he gathered largely from discussion with other engineers and observation of their works. Books on engineering subjects were few and principally in foreign languages. As a consequence of this, and, "impressed by what they themselves felt with the difficulties young men had to contend with in gaining the knowledge requisite for the diversified practice of engineering," a few young men now nearly a hundred years ago, formed themselves into that venerable organization upon which all engineering societies in the English-speaking world have been directly or indirectly based—the Institution of Civil Engineers of Great Britain. Under existing conditions it was not to be expected that altruistic motives would predominate, and so in the original constitution of the new society we find that it was formed for "the acquirement of professional knowledge, and for promoting mechanical philosophy." Led by the great Telford, its first president drawn from the ranks of already-famous engineers, the Institution prospered and its usefulness grew apace. From the beginning the great personal assistance derived from papers and discussions fully justified this initial effort in the organization of English-speaking engineers.

But the field of the technical society does not end with the dissemination of useful scientific knowledge, however important that may be. There are many activities entered into by the great organizations of technically-trained men which ultimately serve the engineer much more than by extending his knowledge. One line of action of a great engineering society which commends itself to all, and which merits increased attention, is the effort to safeguard the interests of the profession and to raise a defensive front as wide as the continent against unfair treatment of our own engineers. The importation of foreign engineers to do work for which our own men are capable and ready; the malicious attacks of vote-catching politicians and second-rate newspapers, on able and upright members of the profession; the blocking of legislation calculated to raise the standing of the engineer, and place him on a footing with other professional men—these are a few of the injustices which are now engaging the thought of the foremost men in the great engineering organizations.

Still more effective than these external activities are the efforts of the profession to improve its status from within. There are now, thanks to the engineering societies, certain well-recognized principles of professional conduct which, while not commanding that full adherence they deserve, are receiving a growing observance. Among representative members of the engineering body, it is as uncommon for an unfair advantage to be taken of a rival as it is among those who practice the healing art. Out of this springs a larger respect for the engineer, and a fuller recognition on the part of the public of his integrity and the dignity of the profession in which he is engaged.

Reassuring though these beginnings of corporate action have been, there is a vaster work, by far, ahead. We have done almost nothing, compared with what might have been done, and what must be done if the engineering profession is ever to come fully to its own. The promotion of engineering education—the first care of the technical societies in their early years—has been of immeasurable importance to both the young engineer and the established practitioner, but no organization of engineers can adequately fulfil its mission on that basis alone. Nor can purely defensive measures, coupled with technical efficiency, bring about the desired result. Nothing short of aggressive, constructive work of a public, and even of a national character can bring engineers as a body into that enviable position now occupied by such organizations as, for example, our Boards of Trade—bodies which, while formed primarily for the furtherance of their own interests, do a vast deal of invaluable work for the public. On all public questions involving great constructional projects, such as national railways, improvements of navigation or public development and transmission of power, no organizations could with greater weight or propriety express their views than the great national engineering societies. As a result of bringing to bear on public questions of commanding importance a weight of valuable technical opinion, there would arise that prestige and public regard which should rightly be associated with great professional organizations.

If this high ideal of public service is ever to be realized it must gain its impetus from the concerted action of the younger men of the profession. Most great reforms have their sources in the generous enthusiasms of youth. The actualizing of the idea may be possible only by the steady support and co-operation of men of mature years and large experience, but the driving force must come from those whose work is in the future rather than in the past. In any such action numbers in themselves lend confidence. At Waterloo, the appearance of Bülow's division encouraged the whole wavering British line to assume the offensive. An assurance of loyal and extensive support in worthy movements, more than anything else, determines the policy of an organization. The aggressive institution needs the constant accession of new men with fresh ideas and unspent energies.

Practically, the service of the young engineer to the organized profession may come in a variety of ways. He should join the societies or associations in which his interests chiefly lie; he should regularly attend their meetings and discussions and contribute whatsoever of his own that may be of value; he should be willing to accept office or membership on committees, but only in so far as may be consistent with effective service; he should co-operate loyally with the other members of his association in putting its official views before the public; he should, as a member of his society, rush to the defensive in speech or in writing when the profession or any worthy member of it is subjected to an unjust attack; and he should, finally, so conduct himself professionally and privately that those who have withheld their sanction of engineering as a profession will be forced to accord to it that honorable position which has characterized the ancient pursuits of medicine, law and divinity.

As with all unselfish acts, the young engineer in giving his best to the society of which he is a member, derives a personal advantage not attainable by those who stand apart from their fellows. The preparation of papers and discussions is in itself a training, as the early engineers found, of the greatest value. There is nothing which can quite so well clarify one's ideas on a given subject as an attempt to explain it to others either verbally or in writing. The intensiveness of thought essential to carrying on an effective discussion coupled with the suggestiveness of an opponent's questions bring to light ideas which before were unthought of. All this is apart, of course, from the receipt of numerous valuable professional papers which are incorporated in the proceedings or transactions of the great technical societies and which constitute a perquisite of members of all grades. Such literature is of the greatest consequence, and particularly so to the young engineer. The subjects treated are covered more fully here than in text-books or even in the pages of the technical journals. Besides the original papers, many pages of discussion, often of quite as great value as the papers, are published from which commentary ideas of considerable assistance to the young engineer are gleaned. There is also the advantage which the possessor of such a series of proceedings enjoys, in that the matter therein presented is available months, or perhaps years, before it makes its appearance in text-books.

A personal advantage which the member of a technical society of national standing enjoys is the classification which it gives him. The holding of a certain grade of membership is a certificate of experience of a minimum extent and is, in some measure, a testimonial of good character. If nothing more is gleaned from this by a prospective employer or client than a generally favorable impression of the standing of the applicant, it has served its purpose well. In all the great national engineering societies, the possession of Membership—the highest grade—is greatly coveted and counted a professional asset of no mean value.

Covering, perhaps, every branch of engineering or applied science and art, there are technical societies of high standing which are ready and willing to admit the young engineer or technically-trained worker on easy conditions. Without exception they look upon the accession of the young men to membership with favor and even concern. The influence of every such organization will largely be measured by its numbers, and every new recruit added to the list means another member who may some day stand high in the councils of the society and bring honor and dignity to it and to the profession which it aims to safeguard. For those interested in the various departments of civil engineering, in the broad sense, and including therefore mining, mechanical and electrical engineering, there is our own Canadian Society of Civil Engineers—the pioneer national engineering society of Canada. For the specialist in mining and metallurgical engineering there is the Canadian Mining Institute and the Institution of Mining and Metallurgy of Great Britain. The mechanical engineer may find it profitable to be enrolled on the membership list of the Institution of Mechanical Engineers of Great Britain or the American Society of Mechanical Engineers; and for the electrical engineer, there is the American Institute of Electrical Engineers. The young architect will find it desirable to identify himself at the earliest possible moment with the Association of Architects of his own province. The chemist and the chemical engineer has a choice of a number of organizations of which the Society of Chemical Industry is, in Canada, perhaps the most popular.

Finally, let it be impressed upon the young engineer, that if he would make the best of himself, and be of most value to the public at large, he should lose no time in associating himself with those engineering organizations of which he is by training and taste best qualified to become a member.

THE UNIVERSITY CLUB OF REGINA

On March 16, 1912, the first annual dinner of the University Club of Regina was held, "amid," according to the local press, "a series of most unearthly yells, with echoes flying into the farthest corners of the hotel." Some forty guests were in attendance, representing the following universities: Oxford, Liverpool, Aberdeen, Edinburgh, Glasgow, Mount Allison, Manitoba, Queen's, McGill, and Toronto. With their hearts atune to the old-time slogans, which many of them had not heard for years, they revealed, in the proposals and replies ensuing from the toast list, a very thorough appreciation of the aims and motives of the organization.

Mr. J. F. Bole, M.L.A., proposed the toast to "Our Country," dwelling particularly on the need of more thorough appreciation of higher things than dollars and cents, particularly in the western part of our land, a need which, as an old-timer, he has seen grow more and more pressing. He believed that the University Club should be a strong factor in promoting the desire for a higher type of citizenship, and as such he believed it would be welcomed.

"Our Province" was proposed by A. D. Anderson, who gave some striking illustrations of the possibilities and growing importance of Saskatchewan, and in conclusion suggested that we should not forget to "boost Saskatchewan" as well as particular cities. In reply, Dr. Corbett called on the club to remember its particular duties of citizenship to Saskatchewan, the land which had presented wider opportunities than older lands to most of those present.

In proposing "Our Alma Maters," S. R. Curtin, secretary-treasurer of the club, reminded the members that what our Alma Mater expects of her children is an effort to serve the best interests of humanity instead of an entire devotion to material gain. She expects each of her children to help toward a higher social plane in which life will be more livable and men and women more lovable.

In reply to the toast the honorary president, Dr. Andrews, spoke of the ideals set up by a university. These ideals should reach higher than town lots. The best enjoyment is intellectual enjoyment, and this in turn should fit a man for the highest duties of citizenship and give him ideals which would be for the service of humanity. The doctor drew attention to the fact that when the college man graduates he is a debtor to society, for he has not paid for the advantages which have only been made possible by the philanthropy of those who make universities possible, and for the devotion of those teachers in the university who devote their lives to work which gives a small material recompense.

"The Capital City" was proposed by J. A. Westman. He assured the club that although he was not a university man, he, as well as Regina's business men as a whole, was in sympathy with such worthy aims as those of the club.

He remarked that it must not be forgotten that Regina had already a high standard of primary and secondary education and had a flourishing college. Everything that would further educational ends would be welcomed by all business men of the city, who, he believed, had the highest interests of the city at heart, and through whose efforts chiefly the carrying out of those aims is made possible.

In reply Magistrate Trant pointed to the responsibility which rested on university graduates in upholding a worthy standard of citizenship, which has always been placed before them at the university. The spirit and tone of the new universities of the West would be deeply influenced by the spirit of the older universities as revealed in their graduates.

"The University Club" was proposed by Mr. R. E. W. Hagarty, who remarked that the aim of a club such as this one was a complete and sufficient justification for its existence.

In reply, the president of the club, Dr. M. R. Bow, stated that, broadly speaking, the aim of the club was to keep alive and strengthen those university ideals which college men are in danger of losing, particularly in this Western country, and to promote a stronger feeling of brotherhood among the graduates of the city. The club will welcome all who feel a wish for this closer union.

The "School" men present were: Messrs. D. A. Smith, '04; W. A. Begg, '05; H. G. Phillips, '07; R. E. W. Hagarty, '07, and L. S. Cockburn, '10.

THE ENGINEERING SOCIETY ELECTIONS

March 15th, 1912

If one but stops to think he will realize that the changes which have taken place at the School within the last four years are tremendous. The greatest change, of course, is that of the different courses now extended to four years, in the place of the three as hitherto, with the degree of B.A.Sc. at the end of the course. To the influence of this great change, involving as it does the complete reconstruction of the curriculum of each one of the departments, no doubt most of the other changes have to look for their growth.

Now, to one of the old guard, the elections also are greatly changed. They are not quite the same as in the old halcyon days. There was never a better place to hold the elections than in the dear old red brick building, with "Home Sweet Home" so artistically painted at the northern door, the spirit of which few words was so well felt in the days of the classes Naughty-Five to One-ty-One, and before, perhaps. It won't be a great while now before this fond old pile of renovated bricks and mortar becomes a dream of the past and a new building poses in its place, formed as a result of the figuring of the "strong" trio, "John MaC." "C.R." and "Peter." How the floors ran with water from the fire-hose, and how big drafting room "A" rang with the cheers and the yells, never to resound again as they did on the old election nights, will for many a day be fondly cherished in the memory of those who have gone out, to be sadly recalled on returning in the future days when we come back to make a call.

Even next year there will be no gym. in which to hold the elections, and the memory of those few elections, that have been pulled off there, will be carefully laid away in the cupboard of fond recollections.

Things are getting tamer. There can be no doubt of it. It is not many years since voting was only held in the evening and, in order to poll a vote, a man had to run the gauntlet, and as we remember it, it was more than a few small laths and bladders which fell upon him in his course.

This year's elections witnessed the growth and expression of some entirely new platforms, wonderful as it may seem. Old platforms that have existed since the antediluvian days (the days of hoses and three X), such as individual lockers, smoking and reading rooms, etcetera, appeared to be somewhat in the background this year due to new platforms such as: private hospital wards with free attendance for School men; protection by statute of the engineering professions. The latter platform was the one, along with the proposed petition as to School men being permitted to qualify as fire rangers, upon which Mr. J. E. Ritchie was elected as president of the Engineering Society for the coming year.

The elections included this year similar features to those of previous years and some new ones. Tobacco, pipes, fruit, and even sandwiches, were handed out as a reward to those passing through the Mills of the Gods, the Brute Force Committee. An excellent programme was carried out, assisted by the famous School orchestra, under its genial leader, Mr. John Temple, ('11), which was such a fine innovation and so popular that the members of the orchestra were not even allowed to leave their instruments for the time that it would take to go and obtain some fruit. Certainly great credit is to be given to Mr. Temple for his work, which extended over the whole year, and the results produced must have proved gratifying to him.

The basket ball and hockey games (the latter on roller skates and with brooms), and other games, were carried off very nicely, along with the appearance of a bogus School octette, which, as a singing organization, was a failure (the writer being a member of it), but which amply proved its worth as a drawing card for the lemons which were projected from the gallery and elsewhere in the shape of apples and oranges and the remnants of such. However, the "octette" was compensated for the worthy efforts put forth in practice (?) and production, by a beautiful bouquet presented by one of the prominent members of the outgoing executive in the shape of one of the poor wee mutilated flowerlets so ignominiously "pinched" at the Fourth Year Dinner held earlier that evening at the Engineers' Club.

A new and taking innovation at the elections was the presence of a number of very sweet and charming young society belles, whose names, unhappily, were lost in the introduction due to the mob of courteous and well-dressed young gentlemen who waited upon these fair damsels, passionately craving dances and other favors. Never were the ladies so alarmingly popular or so gorgeously decked. These beautiful young ladies were dressed in the very latest from

Paris, **à la decolleté.** One young lady who is certainly worthy of mention was the possessor of one of those beautiful picture hats that Miss Clay so raves over, a most magnificent bunch of garlic, and bunches of other lovely flowers, being painted thereupon, reminding one of the romantic and touching little ballad, entitled "Roses May Die and Violets May Die, but Garlic Lives Forever."

The "Toike Oike," the famous School election journal originated a year ago by Professor Stiles ('07), now of the University of New Brunswick, was published with Mr. P. G. Cherry ('11), as editor-in-chief. It proved to be a satisfactory and an invaluable part of the elections.

When the smoke finally lifted the new executive was found to be made up of the following members:

President, J. E. Ritchie.
1st vice-president, Wm. Curtis.
2nd vice-president, Civils and Architects, F. S. Rutherford.
2nd vice-president, Miners and Chemists, G. M. Smyth.
2nd vice-president, Electricals and Mechanicals, M. F. Verity.
Treasurer, H. R. MacKenzie.
Corresponding Secretary, C. C. Rous.
Recording secretary, J. M. Macdonald.
Curator, G. Rankin.
4th Year representative, H. Hawley.
3rd Year representative, H. N. Macpherson.
2nd Year representative, T. W. Crane.
1st Year representative, to be elected.

LETTER TO DEAN GALBRAITH

Vancouver, B.C., March 11th, 1912.

Dr. J. Galbraith,
Dean, Faculty of Applied Science and Engineering,
University of Toronto, Toronto, Ontario.

Dear Sir:—

. . . . .

It is with pleasure that as secretary I advise you that the Engineering Alumni of the University of Toronto, Pacific Coast Branch, was organized on the 20th of January, 1912. The graduates of the School of Practical Science on the Pacific Coast have long felt that there was such an organization needed, and that it would be to the advantage of the "School" and themselves to have the same formed, but it was only recently that they felt they were numerically strong enough to carry it out.

. . . . .

The idea of the Alumni, apart from the social advantages to its members, is to advance the interests of the Faculty of Applied Science and Engineering of the University of Toronto, to advertise the same on the Pacific Coast, to encourage engineering students from this locality to attend the "School," and to render any assistance to graduates or undergraduates of the Engineering Faculty of the U. of T., who may come or contemplate coming to the Pacific Coast, in familiarizing them with engineering conditions, and, should it be possible, to inform the Faculty in Toronto of any matters coming under our notice conducive to the welfare of the "School," and to supply any information obtainable which the Faculty might desire with reference to this locality.

Should you be pleased to advise the Engineering Society and any of the other societies of the "School" of the organizing of this Alumni, you may also advise them that the secretary here will be pleased to furnish any information which he can to any of the students or graduates with reference to the engineering conditions on the Pacific Coast. A list of the addresses of the members of the Engineering Alumni will be sent as soon as the same is compiled.

. . . . .

With best wishes to yourself and to the Faculty, and for the prosperity of the "School."

Yours very truly,

N. R. ROBERTSON,
Secretary-treasurer.

REVIEWS.

The Manitoba Engineer.

"Applied Science" begs to voice a word of welcome to a new contemporary, "The Manitoba Engineer," published by the Engineering Society of the University of Manitoba. Volume I, No. 1 appeared in March.

The journal has a sprightly and well-balanced appearance, and will fill an important place in the Engineering Faculty of that University. The initial number contains articles covering a wide range of engineering subjects. Among them are: "Stresses in Eccentrically Loaded Columns"; "Electric Arcs," an article on "Manitoba Highway Building," and several dealing with Winnipeg's progress in engineering.

Engineering.

In the issues of "Engineering" (London), for February 23rd and March 1st, appears an illustrated article by Robert W. Angus, Professor of Mechanical Engineering, University of Toronto, descriptive of the Mechanical Engineering Laboratories of this University. The writer has described the arrangement of machinery and plant, individually and collectively, in a very comprehensive manner, citing the advantages and disadvantages that have made themselves apparent in the design and operation of this magnificent laboratory.

OBITUARY

C. O. Hay.

Charles Oliver Sutcliffe Hay was born on the May 13, 1881, at Falkenberg, Ont. In 1900 he entered Pickering College and graduated from there in 1903. The following three years he spent with his father in Falkenberg, being engaged in the lumber business. In 1906 he entered Civil Engineering at the Faculty of Applied Science in the University of Toronto. Here he proved himself an all-round man, his splendid physique enabling him to take a very active part in athletics. He played for the junior, intermediate and senior School rugby teams, and also with the Varsity III. and II. teams.. Graduating in 1909, he left the University well known, and liked by the many who knew him. He then worked for the contractors on the Hydro-Electric Commission as foreman on tower erection, and was promoted to divisional superintendent on construction. In January, 1911, he married Miss Rose Sloan of Toronto, and then went to Montreal as assistant divisional engineer for the Shawinigan Power Co. At Riviere des Prairies, while engaged on this work he contracted typhoid fever, and after a short illness died on Sept. 5th in the Western Hospital. His death is a great loss to his many friends and fellow-workers, for he was, wherever he went, universally liked and respected. The engineering profession has lost a man who was a credit to his calling and who would, of a surety, have made his mark. Our sympathy is extended to his young wife, who has so early suffered such a great loss, and to his father, mother and sisters, for he was an only son and brother.

Chas. O. Hay, '09.

N. D. Whatmough.

The great Porcupine disaster of last summer was brought vitally home to us by the death therein of Norman Whatmough, of the class of '14. Mr. Whatmough was a student in mining engineering, and at the close of the term, went north, engaging in mining work at the Dome Mine. Along with others, he took refuge in a shaft, only to be suffocated by the fumes of the holocaust, all means of escape being cut off. He was most popular and conscientious in his school career, and the cutting short of what promised to be a most successful life, was deeply regretted by his associates and fellow-students.

Jno. E. McDougal.

It was with a shock that the many friends and acquaintances of "Jack" McDougal heard of his death by drowning on the 20th May last, while attempting to paddle up the "Narrows," a dangerous portion of the Back River, the northern branch of the St. Lawrence, at Montreal. Mr. McDougal was born in 1887, and received his public school training at Gladstone School, subsequently attending for a year. He then entered the employ of the Toronto Street Railway, and remained with that company for several years. Desirous of bettering his position, he decided to study engineering, and with this in view, in 1905 he entered the Toronto Technical School, taking a special course and obtaining, in the following year, his matriculation standing with honors. He entered the Faculty of Applied Science to study mechanical and electrical engineering, with the class of '09. Here his sterling qualities and genial disposition made him a general favorite. Here also he further bore out his reputation as a student by taking, with ready facility, his successive examinations with honors. In the interim between college terms he was employed in the engineering department of the City of Toronto, and in the fall of

JNO. MCDOUGAL, '09.

1909 took a position with the Expanded Metal Company. They quickly appreciated his abilities, and sent him to Montreal as their Eastern representative. His untimely death cut short a career which gave every promise of being an exceptionally brilliant one. To his large circle of friends, however, there remains a memory of a buoyancy, and an optimism, that was a pleasure to all with whom he came in contact. The heartfelt sympathy of his classmates is extended to his bereaved parents, to whom he was an only son.

Benjamin J. Redfern.

Particularly sad are the circumstances surrounding the death at the early age of 27 years of Benjamin J. Redfern of the class of '10. Mr. Redfern, the son of Mr. and Mrs. Thomas Redfern of Holly, Ont., received his early education at the Big Bay Point schools and afterwards attended the Barrie Collegiate Institute. He began teaching school at the early age of 17 years, but later took up telegraphy and secured a position with the Grand Trunk Railway. Being of a studious and industrious nature, his interest in electrical engineering resulted in his entering the Faculty of Applied Science and Engineering, from which he graduated in 1910. Upon leaving the University he took up editorial work on "Construction" journal, and later secured a position with the Toronto Hydro-Electric System, which position he retained until a short time prior to his death, caused by tuberculosis of the throat. Mr. Redfern, during his course in the University of Toronto, displayed himself to be of such true manliness and genial disposition which, accompanied by the qualities that promise the ideal engineer as well as man, created in the hearts of his fellow-students a friendship which time will not easily efface.

Ben. J. Redfern, '10.

James Newark Leitch.

Mr. J. N. Leitch, of the class of '10, died on March 24th, 1912, after an illness of several days' duration, having contracted pleurisy which was soon followed by pneumonia. Mr. Leitch was the younger son of Chairman James Leitch of the Ontario Railway and Municipal Board. He graduated from the Faculty of Applied Science and Engineering in 1910, and secured the degree of B.A.Sc. last year. Since enrolling as a student in the University, Mr. Leitch has displayed unusual ability in engineering work, and his summers have been spent in the furthering of his course and extending as far as possible the value of his academic training. The holidays of 1908 he spent on construction work on the Grand Trunk Pacific. His summer of 1909 was devoted to further practical work on the T. & N. O. lines. He spent the vacation of 1910 in the employ of the Ontario Government as structural engineer in the erection of steel bridges. After leaving the University in 1911 he was employed in the Porcupine district. While making a portage with a survey party, he sustained a knee sprain which compelled him to return home, thereby escaping the Porcupine holocaust of last summer by a margin of two days. Prior to his recent illness he was employed as structural engineer on the Government House, Toronto, and was in perfect health until several days before his death. The remains of Mr. Leitch were conveyed to Williamstown, Glengarry, the scene of his boyhood days, for interment.

Jas. N. Leitch, '10.

W. R. Davis, '13.

Mr. W. R. Davis, a member of the class of '13, died at his home in Toronto, on June 12th, 1911. Mr. Davis enrolled in the civil engineering course after having spent a year in the

Engineering Faculty of the University of Manitoba. Towards the end of the session last year, he seriously injured his knee while playing basketball, he being a member of the First Team. The injury prevented him from trying his examinations in April. Mr. Davis went West as instrument man on a Grand Trunk Pacific survey party, but contracted serious illness, which laid him up in Calgary hospital for some time. As soon as his strength permitted, his father had him brought home by easy stages and careful traveling. Mr. Davis did not regain strength, however, and died ten days after his arrival in Toronto. To his relatives we extend most heartfelt sympathy.

W. T. S. Ruston.

Mr. Wilmott T. S. Ruston, of the class of '14, electrical engineering, died at his father's residence in Nortonville, near Brampton, Ont., on Jan. 17th, 1912. Pneumonia was the cause of his early death. Previous to entering upon his University course, Mr. Ruston taught in the public schools for a number of years, but he finally decided to take up engineering as a profession. Although but one year of his course was accomplished, he showed singular ability as a student, securing honors at his examination, and was popular among his fellows. In the academic year he unfortunately injured his foot, which later caused serious development, sufficient to necessitate its amputation. It was considerable time before his health was regained, but he was on the road to favorable recovery when he suffered a fatal attack of pneumonia.

UNIVERSITY OF TORONTO CLUB OF NEW YORK.

Banquet.

The 10th annual banquet took place on Saturday, Feb. 10th, 1912, in the Engineers' Club, 32 West 40th St., and a very enjoyable dinner of fifty it proved to be.

Professor W. J. Alexander and Professor C. H. C. Wright greatly pleased the members with their entertaining speeches. Professor Alexander having already made a great impression on the members of the Republican Club, the chairman of which, hearing that Professor Alexander from Toronto was present, called on him for a speech which, when given, pleased all.

At the banquet the Rev. Karl Reiland of St. Andrews' Church, Yonkers, made a powerful and humorous short address, and was followed by the Rev. Madison C. Peters.

Dr. A. H. Montgomery, president of the club, presided, and also called on Mr. Andrew B. Humphrey of the American Peace and Arbitration League, and E. R. L. Gould for addresses in their usual well turned style.

The Canadian Club of New York was represented by Vice President, E. Medley Scovil; the president of the Canadian Club being also present, as a member of the University of Toronto Club. The New York Graduates' Society of McGill University was represented by Mr. Wickware, while Dr. Robert G. Moore, president of the New York Society of Queen's University, did the honors for Kingston. Our Walter H. Robinson very kindly looked after the musical program and sang several very fine solos himself.

Annual Meeting.

The annual meeting was held in the Engineers' Club, taking place on Thursday, April 11th.

Twenty-seven sat down to a very pleasant dinner in the breakfast-room of the club, and then proceeded with the routine business of the club—electing the following officers for the ensuing year:—

President—Dr. Chas. Graef.
Vice-President (Eng.)—L. L. Brown.
Vice-President (Med.)—Dr. C. J. Patterson.
Vice-President (Art)—C. M. Keys.
For Membership Committee for 3 years—Dr. R. G. Snyder.
Sec.-Treas.—T. Kennard Thomson.

The principal new business transacted was the election of Professors W. J. Alexander and C. H. C. Wright to be Honorary Members of the Club. It was then decided to have the Annual Meeting in the future on the fourth Thursday in April, instead of the second.

The Secretary-Treasurer's report showed the most successful year in the history of the Club.

The meeting then adjourned into the adjoining room, where Mr. John S. Thomson played the piano and the members enjoyed singing the songs of their youth.

T. KENNARD THOMSON,
New York, April 16th, 1912. Sec.-Treas.

G. E. Woodley, '10, is in the transformer department of the Westinghouse Electric Mfg. Co., Pittsburg, Pa. We are pleased to note that Mr. Woodley still maintains his prestige on the cinderpath and has recently won honors at an athletic meet in Pittsburg.

W. M. Carlyle, '10, is secretary of the firm of Carlyle & Beck, Limited, general contractors, Toronto. This firm makes a specialty of reinforced concrete, foundation work, diving and underwater work.

Gordon Kribs, '05, is engineer for the Pacific Coast Power and Light Co., at Portland, Oregon.

W. S. Pardoe, '04, is associate Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

TREASURER'S REPORT

Engineering Building, University of Toronto.
March 30th, 1912.

The Engineering Society,
University of Toronto, Toronto, Ont.

Gentlemen: I beg to submit herein the financial statement of the University of Toronto Engineering Society for the fiscal year ending March 30th, 1912.

Cash Book Balance

RECEIPTS.

Merchandise Sales	$ 8,107.96
Applied Science	1,498.64
Fees	750.00
Telephones*	15.50
Annual Dinner	309.80
Annual Dance	547.00
From 1910-11 Executive	761.58
Outstanding Cheques, March 30, 1912	1,009.73
	$13,000.21

*Telephone banks withdrawn Dec. 30th, 1911

DISBURSEMENTS.

To 1912-13 Executive, Cash	$ 785.68
Supply Department—	
Merchandise	6.806.30
Salaries	1,133.67
Applied Science	1,809.40
Meetings and Entertaining	349.33
Annual Dinner	678.16
Annual Dance	568.20
Telephones	112.00
Sundry Expense	317.39
Accounts Unpaid, March 31, 1911	440.08
	$13,000.21

RESOURCES.

Merchandise as per Inventory, March 30, 1912	$2,206.72
Cash on Hand	280.79
Cash in Bank	504.89
Accounts Due Supply Department	69.38
Accounts Due Applied Science	835.99
Fees Outstanding	40.00
Office Equipment, Less 10 p.c. Depreciation	220.37
	$4,158.14

LIABILITIES.

Accounts Outstanding Supply Department	$ 107.50
Accounts Outstanding Applied Science	82.08
	$ 189.58
Surplus	$3,968.56

Respectfully submitted,
C. F. ELLIOTT.

APPLIED SCIENCE

INCORPORATED WITH

TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Vol. V - New Series

November '11 to April '12

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ENGINEERING BUILDING
UNIVERSITY OF TORONTO, CANADA

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CHANGES OF ADDRESSES

This is not a complete list of addresses. It contains only those addresses that are new since April, 1911, in which number of APPLIED SCIENCE a then complete list was published. Graduates are requested to inform us immediately of changes in their addresses.

1882

1. **D. JEFFREY**............................**Unknown.**

1883

1. G. H. Duggan, M.Can.Soc.C.E..........Montreal, P.Q.
Dominion Bridge Co.

1884

1. **W. C. KIRKLAND**....................**Unknown.**

1886

1. H. G. Tyrrell, C.E., A.M.Can.Soc.C.E. ..Evanston, Ill.
Consulting Engineer.

1887

1. **A. E. LOTT**...........................**Unknown.**
1. **F. MARTIN, M.B., O.L.S.**..............**Unknown.**
Physician

1888

1. **D. B. BROWN, O.L.S.**.................**Unknown.**

1889

1. **B. CAREY**.............................**Unknown.**
1. W. J. Chalmers.........................Vanport, Beaver Co., Pa.
1. G. F. Hanning..........................St. Eustache,
Div. Engineer C.N.R. Two Mountains P.Q.

1891

1. W. B. Russell..........................1307 Traders Bank Bldg.,
Civil Engineer and Contractor. Toronto Ont.

1892

1. J. R. Allan, O.L.S......................Renfrew, Ont
1. **A. G. ANDERSON**.....................**Unknown.**
1. **J. B. GOODWIN**.......................**Unknown.**
5. W. L. Lawson, B.A.Sc..................Sterling, Colo.
Manager, Great Western Sugar Co.

1893

1. C. Forrester............................Indian Head, Sask.
1. T. J. McFarlen..........................Port Arthur, Ont.
Chemist, Atikakan Iron Co.
1. A. J. McPherson, B.A.Sc., D.L.S........Regina, Sask.
City Commissioner.
1. **W. MINES, B.A.Sc**.................. ..**Unknown.**
1. **W. V. TAYLOR, O.L.S., A.M.Can Soc. C.E.**...............................**Unknown.**
1. **R. B. WATSON**........................**Unknown.**

1894

1. H. F. Barker............................Toronto, Ont.
Godson Contracting Co.
1. A. T. Beauregard, B.A.Sc................Verona, N.J.
Laboratory Engineer, Public Service Corporation of New Jersey.
3. **W. J. HERALD, B.A. Sc**...............**Unknown.**
1. S. M. Johnston, B.A.Sc., P.L.S..........Trail, B.C.

1. J. E. Jones..............................149 Broadway, New York, N.Y.
1. **A. L. McTAGGART, B.A.Sc.**............**Unknown.**
1. H. Rolph..................................Lachine, P.Q.

1895

1. E. J. Boswell, D.L.S....................Montreal, P.Q.
   Engineering Dept., C.P. Ry.
3. **W. M. BRODIE, B.A.Sc.**...............**Unknown.**
4. R. J. Campbell..........................Chicago, Ill.
   Western Electric Co.
1. F. W. Guernsey.........................Trail, B.C.
3. **H. S. HULL**...........................**Unknown.**

1896

2. L. T. Burwash...........................White Horse, Y.T.
   Mining Recorder.
3. H. P. Elliott, B.A.Sc., E.E..............Manning Chambers
   Industrial Engineer. Toronto

1897

4. E. A. Forward, A.M.Can.Soc.C.E........Box 2966, Winnipeg, Man.
3. W. A. B. Hicks..........................1833 Wallace St., Philadelphia, Pa.
4. C. F. King,..............................817 Blvd. St. Joseph W., Outremont, Montreal, P.Q.
   Sales Manager, The Railway Asbestos Packing Co. Limited, Sherbrooke and Montreal.
2. A. H. A. Robinson, B.A.Sc., M.A.I.M.E., 497 Gilmour St., Peterborough, Ont.
3. **W. R. SMILEY**.........................**Unknown.**
1. E. A. Weldon.............................413 McIntyre Bldg., Winnipeg Man.
   Real Estate Broker.

1898

3. **J. E. LAVROCK**........................**Unknown.**
4. D. MacKintosh, B.A.Sc., B. Arch ......Brooklyn, N.Y.
   Chief Supt., F. M. Andrews & Co.
1. **F. W. McNAUGHTON, O.L.S.**.........**Unknown.**
3. **A. E. SHIPLEY, B.A.Sc.**...............**Unknown.**
3. F. C. Smallpiece, B.A.Sc.................485Grosvenor St., Westmount P.Q.
   Assistant Manager, Canadian General Electric Co.
1. H. L. Vercoe.............................109 McCaul St., Toronto, Ont.
3. D. A. Williamson, B.A.Sc................Ottawa,

1899

2. J. T. M. Burnside, B.A.Sc...............Toronto.
2. **G. A. CLOTHIER**......................**Unknown.**
3. J. A. Craig, B.A.Sc.......................Prince Albert, Sask.
2. **J. C. ELLIOTT**..........................**Unknown.**
3. **W. E. FORMAN**........................**Unknown.**
3. **E. GUY, B.A.Sc.**.........................**Unknown.**
3. W. Monds, B.A.Sc.........................New York Athletic Club, New York, N.Y.
3. **A. S. H. POPE, B.A.Sc.**................**Unknown.**
3. E. Richards, B.A.Sc......................Toronto, Ont.
   Purchasing Agent, Toronto Hydro-Electric System.

1900

1. J. L. Allan, A.M.Can.Soc.C.E............Dartmouth, N.S
   Assistant Engineer, Intercolonial Ry.
3. **J. CLARK**................................**Unknown.**
3. G. W. Dickson, B.A.Sc....................Grand Mere, P.Q.
   With Laurentide Paper Co.
2. H. S. Holcroft, B.A.Sc., D.L.S...........108 St. Vincent St., Toronto. Ont.
3. H. A. Johnson............................Stetler, Man.

3. **J. C. JOHNSTON**........................**Unknown.**
2. J. G. McMillan, B.A.Sc...................424 Wellington Pl., Toronto, Ont.
   Mining Engineer and Geologist, T. & N. O. Ry.
2. J. R. Roaf, B.A.Sc.......................Edmonton, Alta.
3. **C. H. E. ROUNTHWAITE**..............**Unknown.**

1901

3. **J. T. BROUGHTON**...................**Unknown.**
3. N. R. Gibson, B.A.Sc...................403 Markham St., Toronto.
2. **A. T. E. HAMER**.......................**Unknown.**
3. W. C. Lumbers.............................69 Metcalf St., Toronto.
2. **W. C. MATHESON**....................**Unknown.**
2. J. L. R. Parsons, B.A., D.L.S...........Regina, Sask.
1. G. H. Power..................................108 Dovercourt Rd., Toronto
   Chipman & Power.

1902

3. **J. M. BROWN**............................**Unknown.**
2. **A. R. CAMPBELL**.......................**Unknown.**
2. **F. T. CONLON**..........................**Unknown.**
3. H. V. Connor.................................Hamilton, Ont.
   Canadian Westinghouse Co.
2. W. M. Edwards, B.A.Sc..................205 Sherlock Bldg.,
   Duff & Edwards. Lethbridge Alta.
2. D. L. H. Forbes.............................306 Manning Chambers, Toronto.
   Mining and Metallurgical Engineer.
1. A. E. Gibson, B.A. Sc.....................1253 King St. W., Toronto.
3. **A. C. GOODWIN**.........................**Unknown.**
3. D. M. Johnston..............................107 Beatrice St., Toronto.
3. **R. S. MENNIE**.............................**Unknown.**

1903

3. H. H. Angus, B.A.Sc.......................Confederation Life Bldg., Toronto.
   Consulting Engineer.
2. N. A. Burwash, B.A.Sc....................113 Bloor St. W., Toronto.
3. A. E. Davidson, B.A.Sc...................Niagara Falls, Ont.
3. **R. E. GEORGE**............................**Unknown.**
1. W. A. Gourlay................................Penticton, B.C.
   Locating Engineer for the Kettle River Ry.
5. **J. A. HORTON**.............................**Unknown.**
1. A. L. McNaughton..........................Cornwall, Ont.
3. **C. A. MAUS**.................................**Unknown.**
3. **J. D. PACE, B.A.Sc**......................**Unknown.**
2. J. E. Umbach..................................Victoria, B.C.
   With Surveyor General.
3. S. B. Wass.......................................Fredericton, N.B.
   Constructing Department, St. John and Quebec Ry.
3. **M. B. BONNELL**...........................**Unknown.**

1904

R. J. Burley.......................................Calgary, Alta.
   Dist. Engineer, Irrigation Office,
   Dept. of Interior.
3. F. W. Burnham, B.A.Sc....................4132 Dorchester St. W.,
   Montreal, P.Q.
3. **J. W. CALDER, B.A.Sc.**...................**Unknown.**
1. A. J. Campbell, B.A.Sc.....................Collingwood, Ont.
3. A. M. Campbell, B.A.Sc....................Chilliwack, B.C.
2. C. A. Chilver...................................Walkerville, Ont.
2. H. L. Chilver...................................Walkerville, Ont.
2. P. C. Coates, B.A.Sc........................Revelstoke, B.C.
   Mining Engineer.
3. S. E. Craig......................................Snelgrove, Ont.

1. A. L. Ford, B.A.Sc.......................Prince Rupert, B.C.
Government Inspector, Dept. of Railways and Canals.
1. J. N. Goodall...........................380 Woodville Ave., West, Toronto. Ont.
1. J. P. Gordon...........................Dauphin, Man.
Engineering Staff, Willis Chipman, C.E.
3. W. W. Gray, B.A.Sc....................Medicine Hat, Alta.
1. E. M. M. Hill...........................Edmonton, Alta.
Locating Engineer.
2. C. J. Ingles............................Thorold, Ont.
1. E. A. James............................57 Adelaide St. E., Toronto.
Engineer to York Highway Commissioner.
1. P. V. Jermyn, B.A.Sc..................216 Poplar Plains Rd., Toronto.
C.P.R. Construction Dept.
3. **O. B. McCUAIG, B.A.Sc................Unknown.**
1. **G. G. McEWEN, B.A.Sc................Unknown.**
1. W. G. McFarlane, B.A.Sc...............55 Elliott St., Toronto.
3. C. P. McGibbon, B.A...................Hamilton, Ont.
Canadian Westinghouse Co.
1. D. McMillan...........................Edmonton, Alta.
3. **E. E. MOORE...........................Unknown.**
3. W. H. Munro...........................Peterborough, Ont.
Peterborough Radial Ry.
3. **G. PACE...............................Unknown.**
3. W. S. Pardoe, B.A.Sc..................Philadelphia, Pa.
Associate Professor of Civil Engineering, University of Pennsylvania.
1. D. L. C. Raymond, B.A.Sc..............Toronto, Ont.
Manager, Bishop Construction Co.,
3. M. R. Riddell, B.A.Sc.................86 Spadina Rd., Toronto.
President, Radiant Electric Co.,
3. **S. E. THOMSON.......................Unknown.**
3. C. J. Townsend, B.A.Sc................Moose Jaw, Sask.
Wilson, Townsend and Saunders.
2. E. Wade, B.A..........................Welland, Ont.
Contractor and Builder.
1. J. M. Weir............................Toronto, Ont.
Toronto Plate Glass Importing Co.

1905

3. **C. B. AYLESWORTH.................Unknown.**
3. **G. G. BELL...........................Unknown.**
3. W. R. Carson..........................Cleveland, Ohio.
Grasselli Chemical Co.
1. **A. V. CHASE..........................Unknown.**
1. G. H. Ferguson, B.A.Sc................52 Isabella St., Toronto.
Commission of Conservation.
2. C. S. L. Hertzberg....................Toronto.
Bishop Construction Co.
3. W. G. Hewson, B.A.Sc.................Niagara Falls, Ont.
3. G. Kribs..................................Portland, Oregon.
Pacific Coast Power and Light Co.
2. P. A. Laing ....Dundas, Ont.
2. **D. W. McKENZIE.....................Unknown.**
3. **F. G. MACE..........................Unknown.**
3. G. R. Munro, B.A.Sc...................405 Dorchester St. W., Montreal.
1. **E. D. O'BRIEN.......................Unknown.**
1. E. P. A. Phillips, B.A.Sc., O.L.S.........Oshawa, Ont.
5. T. E. Rothwell, B.A.Sc.................607 Spadina Ave., Toronto, Ont.
2. G. S. Scott............................125 84th St., Brooklyn, N.Y.
3. H. V. Serson...........................Newark, N.J.
Engineer of Construction, Titan Steel Co.

1. H. L. Wagner, B.A.Sc. .... 21 Gerrard St. E., Toronto, Ont.
Structural Dept., Toronto Structural Steel Co.

1906

1. F. Alport .... Redditt, Man.
3. J. C. Armer, B.A.Sc. .... Toronto, Ont.
Sec.-Treas., Commercial Press, Ltd.
2. G. W. Bissett .... Porcupine, Ont.
Dome Mines.
1. A. E. K. Bunnell, B.A.Sc. .... 61 Grosvenor St., Toronto.
3. F. M. Byam .... 43 Churchill Ave., Toronto.
With McGregor & McIntyre.
3. A. Cameron .... Winnipeg, Man.
Vulcan Iron Works Co.
3. **A. W. CAMPBELL, B.A.,Sc.** .... **Unknown.**
1. E. L. Cousins, B.A.Sc. .... 32 Laburnam Ave., Toronto.
Engineer to Harbour Commission.
1. A. L. Harkness, B.A.Sc. .... Montreal, P.Q.
St. Lawrence Bridge Co., Limited.
1. E. Harrison, B.A.Sc. .... 513 Beveridge Bldg., Calgary, Alta
Ponton & Harrison.
1. R. S. Houston .... Winnipeg, Man.
Vulcan Iron Works Co.
1. A. E. Jupp, B.A.Sc. .... 165 Bolton Ave., Toronto.
3. J. D. Keppy .... 46 Ulster St., Toronto.
Hamilton Gear & Machine Co.
3. A. P. Linton, B.A.Sc. .... Montreal, P.Q.
With St. Lawrence Bridge Co.
2. J. A. McKenzie .... Vancouver, B.C.
1. J. V. McNab .... Moose Jaw, Sask.
C.P.R. Engineering Dept.
3. J. A. McPherson .... Bolsover, Ont.
2. K. A. MacKenzie, B.A.Sc. .... Vancouver, B.C.
1. W. MacKinnon .... Wilkinsburg, Pa.
3. W. MacLachlan, B.A.Sc. .... Belleville, Ont.
Manager, Trenton Electric & Water Co.
3. W. A. Maxwell .... 123 Fisher St., Detroit, Mich.
2. C. J. Murphy, B.A.Sc. .... Fernie, B.C.
Chief Engineer, Crow's Nest Pass Coal Co.
5. R. E. Pettingill .... Port Colborne Ont.
Chief Chemist, Canada Cement Co.
3. N. R. Robertson, B.A.Sc. .... 202 Winch Bldg., Vancouver B.C.
1. **J. O. RODDICK** .... **Unknown.**
2. O. Rolfsen, B.A.Sc., D.L.S. .... Walkerville, Ont.
Dept. of the Interior.
2. J. H. Ryckman .... 7323 Stewart Ave., Chicago. Ill.
Construction Dept., Chicago, R. I. & Pacific Ry.
2. J. E. Thomson, B.A.Sc. .... 57 Queen's Park, Toronto. Ont.
3. **J. N. WILSON, B.A.Sc.** .... **Unknown.**
3. E. M. Wood, B.A.Sc. .... Toronto, Ont.
Engineering Dept., Canadian General Electric Co.

1907

3. H. D. Bowman, B.A.Sc. .... 309 Ontario St., London. Ont.
1. G. H. Broughton .... Penticton, B.C.
Manager, People's Trust Co., Ltd.
1. **J. A. BROWN, B.A.Sc.** .... **Unknown.**
1. C. E. Bush, B.A.Sc. .... 156 Geoffrey St., Toronto, Ont.
1. E. Cavell .... 182 Sunnyside Ave., Toronto, Ont.
Fellow in Surveying, University of Toronto.
3. G. C. Cowper, B.A.Sc. .... Welland, Ont.

2. **J. V. CULBERT, B.A.Sc.** .... **Unknown.**
3. F. R. Ewart, B.A.Sc. .... 44 Sussex Ave., Toronto, Ont.
Smith, Kerry & Chace.
1. J. S. Galletly .... Brooklin, Ont.
1. A. Gillies, B.A.Sc. .... Minnedosa, Man.
1. R. E. W. Hagarty, B.A.Sc. .... Vancouver, B.C.
1. C. T. Hamilton, B.A.Sc. .... Vancouver, B.C.
1. T. H. Hogg, B.A.Sc. .... Toronto, Ont.
Editor, Canadian Engineer, 62 Church St.
4. C. B. Jackson .... Chicago, Ill.
Chief Engineer, Estimating Dept. C. Everett Clark Co.
3. D. F. Keith .... Toronto, Ont.
Keith & Fitzsimmons.
1. H. P. Keith .... Edmonton, Alta.
Smith & Keith, Surveyors and Engineers.
1. L. W. Klingner .... Smith's Falls, Ont.
Res. Engineer, C.P.R.
1. J. H. Lindsay .... Hornby, Ont.
3. D. J. McGugan, B.A.Sc. .... Box 231, New Westminster, B.C.
With Hill & Burnett.
3. **F. W. McNEILL, B.A.Sc.** .... **Unknown.**
1. M. K. McQuarrie .... Revelstoke, B.C.
Resident Engineer, C.P.R. Co.
3. J. B. Minns, B.A.Sc. .... 102 College St., Toronto, Ont.
1. E. W. Murray .... Regina, Sask.
Department of Public Works.
3. **J. D. MURRAY** .... **Unknown.**
1. A. E. Nourse .... Montreal, P.Q.
With C. W. Noble.
1. R. B. Potter, B.A.Sc. .... 235 Garden Ave., Toronto, Ont.
Dept. of Roadways, City Engineer's Office.
3. G. E. Quance, B.A.Sc. .... Delhi. Ont.
Secretary-treasurer, The Delhi Light & Power Co.
1. **A. C. T. SHEPPARD** .... **Unknown.**
3. E. R. Smithrim, B.A.Sc. .... Watrous, Sask.
Watrous Electric Light, Power & Traction Co.
1. W. Snaith .... 493 Brunswick Ave.. Toronto.
Assistant Engineer to Frank Barber.
3. A. C. Spencer, B.A.Sc. .... Hamilton, Ont.
Mechanical Engineer, Hamilton Stove & Heater Co.
1. J. A. Stiles, B.A.Sc. .... Fredericton, N.B.
Professor of Civil Engineering, University of New Brunswick.
3. O. R. Thomson, B.A.Sc. .... Highgate, Ont.
3. **A. F. WILSON, B.A.Sc.** .... **Unknown.**
3. M. H. Woods .... Aylmer West, Ont.

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5. J. R. Arens, B.A.Sc. .... Orillia, Ont.
3. H. C. Barber, B.A.Sc. .... 88 St. Albans St., Toronto, Ont.
2. F. J. Bedford .... Lakefield, Ont.
3. J. H. Brace .... 171 Harvard Ave., Montreal, Que.
1. P. R. Brecken, B.A.Sc. .... 31 Howland Ave., Toronto.
3. E. I. Brown .... Paris, Ont.
2. J. E. Campbell, B.A.Sc. .... Coldstream, Ont.
1. R. Y. Cory, B.A.Sc. .... 3 Deer Park Crescent, Toronto,
1. F. A. Danks .... 544 Gladstone Ave., Toronto.

3. H. C. Doorly..........................5 Geneva St., St. Catharines, Ont.
Assistant Engineer, Jenckes Machine Co.
1. F. M. Eagleson........................Winchester, Ont.
Land Surveyor.
1. C. Flint, B.A.Sc......................Winnipeg, Man.
Asst. Engineer, C.P.R.
1. A. H. Foster, B.A.Sc..................Cochrane, Ont.
Resident Engineer, T.C.R.
3. G. C. Francis.........................Verschoyle, Ont.
3. C. L. Gulley, B.A.Sc..................328 Broadview Ave., Toronto, Ont.
With Toronto Electric Light Co.
3. J. W. Hackner, B.A.Sc.................Sanford, Ont.
With Continental Rubber Co.
5. D. J. Huether, B.A.Sc.................Torreon, Coahuila Co., Mexico.
3. S. B. Iler............................Belleville, Ont.
Construction Dept., Midland Construction Co.
2. H. G. Kennedy, B.A.Sc.................22 Grenville St., Toronto, Ont.
5. K. D. Marlatt.........................Oakville, Ont.
The Marlatt & Armstrong Co.
5. G. L. Milligan, B.A.Sc................Brampton, Ont.
3. E. D. Monk, B.A.Sc....................Pittsfield, Mass.
Commercial Engineering, General Electric Co.
3. F. H. Moody, B.A.Sc...................Toronto, Ont.
Mechanical Editor of Railway and Marine World.
1. H. J. Peckover, B.A.Sc................205 Dunn Ave., Toronto.
3. M. Pivnick, B.A.Sc....................Maxwell, Ont.
3. C. F. Publow, B.A.Sc..................Davidson, Sask.
1. J. T. Ransom, B.A.Sc..................470 Manning Ave., Toronto, Ont.
Dominion Land Surveyor.
1. W. B. Redfern, B.A.Sc.................Steelton, Ont.
5. F. A. Robertson.......................Toronto, Ont.
Canadian Inspecting & Testing Laboratories.
1. **W. A. ROBINSON**....................**Unknown.**
3. R. C. Robinson........................134 Edmonton St., Winnipeg, Man
Asst. Engr. Bridge Dept., C.N.R.
2. R. R. Rose, B.A.Sc....................473 Euclid Ave.
3. H. F. Shearer, B.A.Sc.................Toronto, Ont.
Smith, Kerry & Chace.
1. **J. J. STOCK**.......................**Unknown.**
3. A. D. Sword, B.A.Sc...................220 Rusholme Road, Toronto.
3. V. C. Thomas, B.A.Sc..................28 Langley Ave., Toronto, Ont.
1. J. H. Thornley, B.A.Sc................Niagara Falls, Ont.
With H. D. Symmes & Co.
3. C. P. VanNorman, B.A.Sc...............282 Carlton St., Toronto. Ont.
1. J. A. Walker, B.A.Sc..................Vancouver, B.C.
Office of Surveyor General.
3. B. W. Waugh...........................126 Courtland Ave., Berlin, Ont.
3. R. P. Weir............................123 Markham St., Toronto, Ont.
With Toronto Hydro-Electric System.
3. F. D. Wilson..........................60 Howard St., Toronto, Ont.
Structural Dept., Canada Foundry Co.
1. D. O. Wing............................1116 Burrard St., Vancouver, B.C.

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3. H. V. Armstrong.......................364 Victoria St., Toronto, Ont.
With W. Fry Scott.
2. E. T. Austin, B.A.Sc..................Coniston, Ont.
Mond Nickel Co.

1. G. A. Bennett, B.A.Sc....................Eden, Ont.
Dominion Land Surveyor.
3. E. R. Birchard, B.A.Sc..................West Toronto, Ont.
Russell Motor Car Co.
3. D. C. Blizard, B.A.Sc...................225 Huron St., Toronto, Ont.
Engineer on Construction, Toronto Structural Steel Co.
1. W. J. Boulton.........................Toronto, Ont.
Post graduate course in Engineering, University of Toronto.
3. J. E. Burns, B.A.Sc....................231 Seaton St., Toronto, Ont
Assistant Manager, Maclean Daily Reports.
1. C. G. Cline, B.A.Sc....................Box 429, Kamloops, B.C.
Hydrographic Survey, Dept. of the Interior.
3. W. E. Corman.........................Toronto, Ont.
With C. H. & P.H. Mitchell, 1005 Traders Bank Bldg.
3. T. H. Crosby, B.A.Sc..................Toronto, Ont.
Demonstrator, Electrical Engineering, University of Toronto.
3. R. H. Cunningham.....................82 Grange Ave., Toronto.
With MacBeth Evans Co.
1. F. A. Dallyn, B.A.Sc...................1488 King St. W., Toronto, Ont.
Engineer-inCharge, Experimental Station, Ontario Board of Health.
1. E. M. Dann..........................Ottawa, Ont.
Waterpowers Branch, Dept. of the Interior.
2. A. I. Davis, B.A.Sc....................Northbrook, Ont.
Superintendent, Ore Chimney Mining Co., Kaladar.
1. F. S. Falconer, B.A.Sc..................127 Slater St., Ottawa.
Dept. of the Interior.
1. J. B. Ferguson........................3302 Vernon Ave., Chicago, Ill.
3. A. T. Fergusson, B.A.Sc................70 Madison Ave., Toronto, Ont.
3. E. R. Frost, B.A.Sc....................Lachine, P.Q.
Dominion Bridge Co.
1. A. E. Glover, B.A.Sc...................Edmonton, Alta.
1. J. E. Gray, B.A.Sc.....................Uxbridge, Ont.
1. W. H. Greene.........................Moose Jaw, Sask.
Assistant City Engineer.
3. C. J. Harper..........................Orangeville, Ont.
1. C. O. Hay (deceased)
3. J. Hemphill...........................Sault Ste. Marie, Ont.
Mines Dept., Lake Superior Iron & Steel Co.
3. C. R. Holmes, B.A.Sc..................Detroit, Mich.
Electric Storage Battery Co.
1. G. C. Hoshal, B.A.Sc..................Weyburn, Sask.
1. **A. E. HUNTER, B.A.Sc.**................**Unknown.**
3. J. Isbister, B.A.Sc.....................Victoria Mines, Ont.
Electrical Engineer, Mond Nickel Co.
1. C. E. Johnston, B.A.Sc.................589 Bathurst St., Toronto, Ont.
1. W. J. Johnston........................Vancouver, B.C.
Mackenzie, Broadfoot & Johnston.
3. W. R. Key, B.A.Sc.....................Toronto, Ont.
Fellow in Applied Mechanics, University of Toronto.
1. R. W. E. Loucks.......................Delisle, Sask.
Assistant to T. W. Brown, C.E.
1. N. C. A. Lloyd........................Solina, Ont.
3. E. D. MacFarlane, B.A.Sc...............Lynn, Mass.
General Electric Company.

1. J. G. MacKinnon........................Winnipeg, Man.
Optical Dept., The T. Eaton Co.
3. D. D. McAlpine, B.A.Sc................Kakabeka Falls, Ont.
3. C. R. McCollum, B.A.Sc................18 Hewitt Ave., Toronto. Ont.
Inspector, Toronto Hydro-Electric System.
3. A. S. McCordick. B.A.Sc...............Toronto, Ont.
Assistant Engineer, Toronto Hydro-Electric System.
3. W. G. McIntosh........................Toronto, Ont.
Post-graduate course in Engineering, University of Toronto.
1 V. McMillan, B.A.Sc...................North Bay, Ont.
Divisional Engineer, C.N.R.
3. N. H. Manning, B.A.Sc.................Oshawa, Ont.
1. A. B. Manson, B.A.Sc..................Ruel, Ont.
Div. Engineer, C.N.R.
1. E. S. Martindale, B.A.Sc..............Aylmer, Ont.
1. O. W. Martyn, B.A.Sc..................Regina, Sask.
Surveyor.
2. C. A. Morris, B.A.Sc..................Copper Cliff, Ont.
Mine Surveyor, Canadian Copper Co.
1. F. V. Munro, B.A.Sc...................Toronto, Ont.
City Engineer's Office.
1. E. A. Neville, B.A.Sc.................Ruthven, Ont.
1. J. Newton, B.A.Sc.....................Montreal, P.Q.
3. L. S. Odell...........................Calgary, Alta.
3. V. J. O'Donnell.......................Toronto, Ont.
Post-graduate course in Engineering, University of Toronto.
1. A. W. Pae.............................Calgary, Alta.
Davidson & Pae, Surveyors.
1. R. B. Pigott..........................157 Wentworth St. S., Hamilton, Ont.
2. G. M. Ponton..........................Calgary, Alta.
Harrison & Ponton.
1. C. R. Redfern, B.A.Sc.................Toronto, Ont.
Demonstrator in Drawing, University of Toronto.
3. L. T. Rutledge, B.A.Sc................Toronto, Ont.
Demonstrator in Drawing, University of Toronto.
3. R. A. Sara, B.A.Sc....................Winnipeg, Man.
City Engineer's Office.
3. A. Schlarbaum, B.A.Sc.................Galt, Ont.
1. **A. SEDGWICK**........................**Unknown.**
1. B. H. Segre...........................Toronto, Ont.
Post-graduate course in Engineering, University of Toronto.
1. F. V. Seibert.........................Toronto, Ont.
Post-graduate course in Engineering, University of Toronto.
3. M. W. Sparling, B.A.Sc................Trenton, Ont.
Sidney Light, Heat & Power Co.
1. N. C. Stewart, B.A.Sc.................Hazelton, B.C.
Green Bros., Burden & Co.
1. J. C. Street, B.A.Sc..................37 Breadalbane St., Toronto, Ont
3. S. Stroud, B.A.Sc.....................Toronto, Ont.
Canadian Westinghouse Co.
1. C. C. Sutherland, B.A.Sc..............446 Heiminck St., Edmonton, Alta.
1. R. G. Swan, B.A.Sc....................Kincardine, Ont.
1. A. D. Sword, B.A.Sc...................220 Rusholme Road, Toronto, Ont
1. H. W. Tate, B.A.Sc....................Toronto, Ont.
Chas. E. Goad & Co.

3. E. A. Thompson........................Lachine, P.Q.
Dominion Bridge Co.
1. G. A. Tipper, B.A.Sc...................Brantford, Ont.
Surveyor.
3. A. G. Trees, B.A.Sc....................Toronto, Ont.
Samuel Trees & Co.
3. W. G. Turnbull, B.A.Sc.................Toronto, Ont.
Chief Engineer, Turnbull Elevator Co.
1. J. E. Underwood.......................Saskatoon, Sask.
McArthur, Murphy & Underwood.
1. C. P. VanNorman, B.A.Sc..............282 Carlton St., Toronto, Ont.
1. J. VanNostrand........................97 Delaware Ave., Toronto, Ont.
1. C. M. Walker, B.A.Sc.................London, Ont.
Dominion Land Surveyor.
3. F. C. White, B.A.Sc...................Lachine, P.Q.
Dominion Bridge Co.
3. A. R. Whitelaw.......................Lindsay, Ont.
With Smith Kerry and Chace.
5. J. A. McK. Williams, B.A.Sc............Toronto, Ont.
Fellow in Chemistry, University of Toronto.
1. O. G. T. Williamson, B.A.Sc............3304 S. Vernon St. ,Chicago, Ill.
3. L. R. Wilson, B.A.Sc..................Montreal, P.Q.
St. Lawrence Bridge Co.
3. F. F. Wilson, B.A.Sc..................Edmonton, Alta.
2. S. A. Wookey, B.A.Sc..................Porcupine, Ont.
Pearl Lake Mine.

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2. J. H. Adams, B.A.Sc...................25 Maynard Ave., Toronto, Ont.
1. W. G. Amsden, B.A.Sc.................95 Howland Ave., Toronto, Ont.
1. J. A. Baird, B.A.Sc....................Leamington, Ont.
1. W. J. Baird...........................Toronto, Ont.
Post-Graduate course in Engineering, University of Toronto.
1. H. A. Barnett, B.A.Sc..................125 Yorkville Ave., Toronto, Ont.
2. D. G. Bissett, B.A.Sc..................Porcupine, Ont.
Dome Mines.
1. R. H. H. Blackwell....................Biscotasing, Ont.
Resident Engineer, C.N.O.
1. E. P. Bowman, B.A.Sc.................West Montrose, Ont.
2. A. F. Brock, B.A.Sc...................Copper Cliff, Ont.
With Canadian Copper Co.
3. J. R. Burgess, B.A.Sc..................Havelock, Ont.
1. G. H. Burnham.......................Toronto, Ont.
Post-graduate course in Engineering, University of Toronto.
3. W. C. Cale...........................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
2. A. D. Campbell, B.A.Sc................Cobalt, Ont.
Engineer, O'Brien Mine.
3. W. M. Carlyle, B.A.Sc.,................Toronto, Ont.
Secretary, Carlyle & Beck, Contractors.
1. D. C. Chisholm, B.A.Sc................Winnipeg, Man.
3. A. W. Chesnut, B.A.Sc.................71 Walker Ave.
3. L. S. Cockburn, B.A.Sc.................Regina, Sask.
Consulting Engineer.
1. H. S. Clark, B.A.Sc....................Port Dalhousie, Ont.
3. A. G. Code, B.A.Sc....................Hamilton, Ont.
Canadian Westinghouse Co.

1910—*Continued*

3. C. R. Cole............................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
1. G. A. Colquhoun, B.A.Sc................Vankleek Hill, Ont.
4. J. H. Craig............................Toronto, Ont.
Post-graduateC ourse in Engineering University of Toronto.
3. C. D. Dean, B.A.Sc....................Sarnia, Ont.
3. R. L. Dobbin, B.A.Sc..................Caron, Sask.
With W. J. Francis & Co.
3. W. P. Dobson, B.A.Sc..................Toronto, Ont.
With Hydro-Electro Power Commission.
2. V. H. Henry, B.A.Sc...................Porcupine, Ont.
Assistant Manager, McIntyre Mines.
3. W. J. Evans...........................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
3. H. W. Fairlie.........................Montreal, Que.
Northern Electric & Mfg. Co.
3. C. R. Ferguson, B.A.Sc................Brampton, Ont.
3. J. W. Ferguson, B.A.Sc................Lachine, P.Q.
Dominion Bridge Co.
4. J. B. K. Fisken, B.A.Sc...............Toronto, Ont.
Demonstrator in Drawing, University of Toronto.
1. A. W. Fletcher, B.A.Sc................Calgary, Alta.
Surveyor.
3. F. T. Fletcher, B.A.Sc................Calgary, Alta.
3. T. R. C. Flint........................12 Galley Ave., Toronto.
2. J. M. Foreman, B.A.Sc.................Lucan, Ont.
3. W. C. Foulds, B.A.Sc..................70 Spadina Rd., Toronto, Ont.
1. A. Fraser, B.A.Sc.....................Toronto, Ont.
Fellow in Physics, University of Toronto.
1. M. M. Gibson, B.A.Sc..................Willowdale, Ont.
With W. S. Gibson, O.L.S., C.E.
1. V. A. E. Goad, B.A.Sc.................Toronto, Ont.
Chas. E. Goad Co.
1. H. Gall, B.A.Sc.......................Toronto, Ont.
With Canada Foundry Co.
3. V. S. Goodeve.........................Toronto, Ont.
Canadian Westinghouse Co.
3. V. F. Gourley, B.A.Sc.................Galt, Ont.
2. R. L. Greene, B.A.Sc..................Toronto, Ont.
Parliament Buildings.
5. J. H. Harris, B.A.Sc..................Danforth Ave., Toronto.
1. N. J. Harvie, B.A.Sc..................Orillia, Ont.
3. F. G. Hickling........................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
2. P. E. Hopkins, B.A.Sc.................Porcupine, Ont.
Ontario Bureau of Mines.
2. F. L. James, B.A.Sc...................Tilsonburg, Ont.
1. H. C. Johnson.........................Toronto, Ont.
1. R. H. Johnston, B.A.Sc................Edmonton, Alta.
1. J. C. Keith, B.A.Sc...................Calgary, Alta.
2. J. T. King............................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
3. G. A. Kingstone, B.A.Sc...............Montreal, Que.
2. G. L. Kirwin, B.A.Sc..................105 St. Vincent St., Toronto, Ont.

1910—*Continued*

5. P. T. Kirwin..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. S. Knight, B.A.Sc......................Bruce Mines, Ont.
With Bruce Mines.
3. E. R. Lawler..........................Toronto, Ont.
Toronto Hydro-electric System.
3. C. B. Leaver, B.A.Sc....................Toronto, Ont.
3. R. G. Lee, B.A.Sc......................Toronto, Ont.
Parliament Buildings.
1. J. N. Leitch (deceased)
3. J. B. Macdonald, B.A.Sc.................Victoria, B.C.
2. A. D. MacDonald......................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
1. J. A. Macdonald, B.A.Sc.................Ridgetown, Ont.
1. G. A. Macdonald, B.A.Sc................Fernie, B.C.
1. A. E. MacGregor.....................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. J. A. Mackinnon, B.A.Sc................212 17th Ave. W., Calgary, Alta.
1. G. G. MacLennan.....................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. D. D. MacLeod, B.A.Sc.................Calgary, Alta.
Hydrographer, Dept. of the Interior.
3. H. G. MacMurchy, B.A.Sc..............Toronto, Ont.
3. H. J. MacTavish, B.A.Sc...............57 Breadalbane St., Toronto, Ont.
4. T. C. McBride, B.A.Sc..................Moose Jaw, Sask.
1. S. G. McDougall, B.A.Sc...............Ottawa, Ont.
1. T. A. McElhanney.....................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. J. McNiven, B.A.Sc...................Winnipeg, Man.
With Dominion Bridge Co.
3. J. I. McSloy, B.A.Sc...................St. Catharines, Ont.
2. A. W. R. Maisonville..................Pilette's Corners, Ont.
1. N. Marr.............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. W. H. Martin, B.A.Sc..................Hamilton, Ont.
With Hamilton Bridge Co.
2. A. C. Matthews.......................89 St. George St., Toronto.
3. H. O. Merriman......................Hamilton, Ont.
Smart Turner Machine Co.
1. D. J. Miller..........................Red Deer, Alta.
Alberta Central Railway.
1. F. S. Milligan........................Toronto, Ont.
Fellow in Mechanical Engineering, University of Toronto.
3. P. E. Mills, B.A.Sc....................52 Howland Ave., Toronto.
3. J. P. Morgan........................Toronto, Ont.
Post-graduate Work in Engineering, University of Toronto.
1. F. R. Mortimer, B.A.Sc................Arva, Ont.
1. A. H. Munro, B.A.Sc...................Peterborough, Ont.
3. J. C. Nash..........................Toronto, Ont.
Post-graduate Work in Engineering, University of Toronto.
1. V. A. Newhall, B.A.Sc.................Calgary, Alta.
Irrigation Surveys, Department of Interior.

1910—*Continued*

2. W. E. Newton, B.A.Sc. . . . . .Silverton, B.C.
Van Roi Mines.
1. F. T. Nichol, B.A.Sc. . . . . .Toronto, Ont.
Asst. Engineer to Clarence W. Noble.
1. C. M. O'Neill, B.A.Sc. . . . . .Erindale, Ont.
3. C. E. Palmer, B.A.Sc. . . . . .Toronto, Ont.
3. G. C. Parker, B.A.Sc. . . . . .Toronto, Ont.
Associate Editor, Motor Magazine.
3. K. K. Pearce, B.A.Sc. . . . . .Port Hope, Ont.
3. C. H. Phillips, B.A.Sc. . . . . .Buffalo, N.Y.
Chief Engineer, Howard Iron Works Co.
1. W. S. Ramsay, B.A.Sc. . . . . .Montreal, P.Q.
Dominion Bridge Co.
3. B. J. Redfern (deceased) . . . .
3. C. E. Richardson. . . . . .Fernie, B.C.
Hydrographic Survey, Department of the Interior.
1. O. W. Ross . . . . .Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
1. W. F. B. Rubidge. . . . . .Toronto, Ont.
Fellow in Drawing, University of Toronto.
3. W. C. Shaw. . . . . .Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
1. W. C. Smith. . . . . .Toronto, Ont
Post-graduate Course in Engineering University of Toronto.
5. **G. E. SMITH**. . . . .**Unknown.**
2. R. J. Spry. . . . . .Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
2. A. L. Steele, B.A.Sc. . . . . .Toronto, Ont.
Fellow in Mining, University of Toronto.
2. H. M. Steven, B.A.Sc. . . . . .Porcupine, Ont.
Hollinger Mine.
1. L. I. Stone. . . . . .Toronto, Ont.
Engineer Maintenance of Way, G.T.R.
3. N. C. Sherman. . . . . .Esquimault, B.C.
Inspector of Ordnance Machinery.
3. A. L. Sutherland, B.A.Sc . . . . .Peterborough, Ont.
Canadian General Electric Co.
3. E. A. Ternan. . . . . .Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
5. W. H. Thom. . . . . .Sarnia, Ont.
Manager, Lyman Drug & Chmical Works.
3. R. M. A. Thompson, B.A.Sc. . . . . .Strathroy, Ont.
3. K. M. VanAllen, B.A.Sc. . . . . .60 Bernard Ave., Toronto
1. L. T. Venney, B.A.Sc. . . . . .Brockville, Ont.
1. R. M. Walker. . . . . .Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. T. Walton, B.A.Sc. .London, Ont.
1. G. A. Warrington, B.A.Sc. . . . . .Cornwall, Ont.
3. M. B. Watson, B.A.Sc. . . . . .Dauphin, Man.
Resident Engineer, with Chipman & Power.

1910—*Continued*

3. H. M. White..........................Lachine Locks,P.Q.
Dominion Bridge Co.
4. W. S. Wickens, B.A.Sc.................Toronto, Ont.
Fellow in Drawing, University of Toronto.
3. G. K. Williams, B.A.Sc.................147 Gore Vale Ave., Toronto, Ont.
1. W. H. Wilson..........................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
1. G. R. Workman.......................Grand Mere, P.Q.
Assistant Engineer, Laurentide Co., Ltd.
3. G. E. Woodley........................East Pittsburg, Pa.
Transformer Dept., West Electric & & Mfg. Co.
3. L. A. Wright, B.A.Sc...................278 Jarvis St., Toronto, Ont.
3. A. W. Youell, B.A.Sc...................Toronto, Ont.
Fellow in Mechanical Engineering, University of Toronto.
1. W. S. Young, B.A.Sc...................Guelph, Ont.

1911

5. J. Aitken.............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. L. B. Allan............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. E. G. Archer..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. L. A. Badgley.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. T. H. Bartley.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. H. L. Batten..........................Aura Lake, Ont.
Surveyor, Barwick Morany & Co.
1. G. L. Berkeley........................Box 62, Belleville, Ont.
3. J. H. Billings.........................Toronto, Ont.
Post-graduate Course in Engineering University of Toronto.
2. J. R. Bissett..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. W. O. Boswell........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. F. Bowman...........................Lachine, P.Q.
Dominion Bridge Co.
3. T. W. Brackinreid.....................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. W. M. Brock..........................Toronto, Ont.
Fellow in Drawing, University of Toronto.
1. W. H. D. Brouse......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. H. Brown............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1911—*Continued*

3. E. T. Cain..................................Box 468, Lachine, P.Q
Dominion Bridge Co.
1. C. S. Cameron..........................Beaverton, Ont.
1. **C. D. CAMPBELL**....................**Unknown.**
6. W. W. Chadwick.......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. R. B. Chandler.........................Toronto, Ont
Post-graduate Course in Engineering, University of Toronto.
1. P. G. Cherry............................Toronto, Ont
Post-graduate Course in Engineering, University of Toronto.
3′. E. F. Chestnut........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. H. J. Clark..............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. F. W. Clark..............................669 Spadina Ave., Toronto, Ont
2. J. E. Clarke.............................139 Dowling Ave., Toronto. Ont.
3. F. S. Cleary.............................34 Crawford Ave., Windsor. Ont.
2. D. B. Cole................................Toronto, Ont
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3′. A. S. Cook..............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. C. W. Cornell...........................17 Charles St. E., Toronto, Ont
1. M. E. Crouch...........................Sault Ste. Marie, Ont.
With Lang & Ross.
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3′. F. K. D'Alton...........................Toronto, Ont.
Post-graduate course in Engineering University of Toronto.
1. W. B. Davis.............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. F. C. DeGuerre........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. F. H. Downing..........................Winnipeg, Man.
Erecting Engineer, Manitoba Bridge & Iron Works.
1. W. B. Dunbar...........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
5. C. H. Eckert.............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. J. A. Elliott..............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

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1. G. R. Elliott..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. C. F. Elliott..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. W. M. Farquharson....................Walkerton, Ont.
1. K. A. Farrell.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. T. J. Farrelly........................Alma, Ont.
1. S. E. Flook...........................Toronto. Ont.
Post-graduate Course in Engineering University of Toronto.
3′. C. C. Flynn..........................18 Picton St., London, Ont.
5 E. L. Frankel.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. J. R. Freeman.........................Toronto. Ont.
Post-graduate Course in Engineering, University of Toronto.
2. E. E. Freeland.......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
4. H. P. Frid............................409 Main St., Hamilton.
3. R. J. Fuller..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. H. D. Fyfe............................722 10th Ave., Vancouver. B.C.
5. J. L. Gooderham......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. T. G. Gravely.........................733 Ontario St., Toronto.
3. R. E. Green..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. E. A. Greene..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. H. G. Hall............................Woodstock. Ont.
1. G. M. Hamilton.......................Toronto. Ont.
Post-graduate Course in Engineering, University of Toronto.
2. H. E. Harcourt........................144 Wilton Ave., Toronto, Ont.
3. M. B. Hastings........................286 Huron St., Toronto, Ont.
3. M. B. Heebner.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. F. I. Nelson..........................Box 64, Newburgh, Ont.
Rodman, C.N.R.
3. H. R. Hill.............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. A. J. Huff............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. K. Huffman..........................30 Cowan Ave., Toronto.
1. H. Hyatt..............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1911—*Continued*

1. R. H. Jarvis..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. L. E. Jones..........................Vancouver. B.C.
City Engineer's Office.
1. E. A. Kelly..........................119 Maryland St., Winnipeg, Man
Resident Engineer Construction, C.P.R.
3′. M. Kirkwood..........................Toronto. Ont.
Post-graduate Course in Engineering, University of Toronto.
2. J. Lanning..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. N. Lawless..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. H. L. Leadman..........................Medina, Ont.
3. W. R. Lethbridge..........................London, Ont.
Care of Thos. C. Knott.
2. M. Lieberman..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. G. L. Lillie..........................642 Spadina Ave., Toronto, Ont.
Inspector, Hydro-Electric.
6. A. L. Long..........................Toronto, Ont
Post-graduate Course in Engineering, University of Toronto.
1. A. W. P. Lowrie..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. W. M. McAndrew..........................Toronto. Ont.
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3′. R. V. Macauley..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
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1. R. E. A. MacBeth..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. E. B. McColl..........................Toronto. Ont.
Engineering Department, G.T.R.
1. F. M. Macdonald..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. W. S. MacKenzie..........................Box 585, Woodstock. Ont.
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1. J. G. MacLaurin..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. J. B. McAndrew..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. J. A. McEachren..........................Strathburn, Ont.
3′. R. W. McElroy..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. H. J. McEwen..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

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1. A. J. McFayden........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3. W. G. McGhie........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. D. A. McKenzie........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. W. S. McKirdy........................Nepigon, Ont.

2. A. J. McLaren........................Toronto, Ont
Post-graduate Course in Engineering, University of Toronto.

3′. A. G. McLeish........................Nairn Centre, Ont
Mond Nickel Co.

1. R. A. McLellan........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

2. W. B. McPherson........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. A. A. McQueen........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

4. H. H. Madill........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. J. C. Martin........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3. C. A. Meadows........................Box 467, Lachine P.Q.
With Dominion Bridge Co.

1. L. G. Mills........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

5. L. C. Mitchell........................Guantanamo, Cuba.
Soledad Estate.

2. J. A. Morphy........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. M. H. Murphy........................Toronto, Ont.
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With Walter J. Francis & Co.

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2. W. A. O'Flynn........................Toronto, Ont.
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1. W. V. Oke............................Toronto Ont
Fellow in Drawing, University of Toronto.
2. J. A. Orr............................Toronto, Ont.
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3′. J. S. Parker............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. J. H. Parkin............................Toronto, Ont.
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Post-graduate Course in Engineering, University of Toronto.
1. R. A. Paul............................69 W.Washington St., Chicago, Ill.
3. C. L. Pearson............................Horseshoe Falls, Kananaskis,Alta.
Operator, Calgary Power Co.
3. W. J. Perrin............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. B. W. Pick............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3′. E. H. Porte............................329 Markham St., Toronto. Ont
1. F. M. Pratt............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
4. H. Pullan............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. L. J. Quinlan............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. L. W. Railton............................4 West Park Road. New Port. Eng
1. J. E. Ratz............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. F. N. Read............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
4. E. V. Reid............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. W. A. Richardson............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. W. E. Robinson............................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. H. L. Roblin............................277 Piccadilly St., London, Ont.
3. L. W. Rothery............................E. Liverpool, Ohio.
Superintendent of Construction, Tri-States Railway & Electric Co.
4. T. L. F. Rowe............................11½ Melbourne Ave., Toronto.
3′. A. S. Runciman............................1151 Tenth St., Calgary, Alta.
3′. F. C. Rust............................29 Admiral Road, Toronto. Ont.

1911—*Continued*

3. F. G. Rutley..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. E. M. Salter..........................Nepigon, Ont.
Division D., C.N.O. Railway.

1. F. R. Scandrett..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

5. J. W. Scott..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. N. D. Seaton..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. D. N. Sharpe..........................407 Builders' Exchange Bldg.,
With Allan Findlay, D.L.S. Winnipeg, Man.

4. P. Sheard..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. W. A. Sibbett..........................Bracebridge, Ont.

2. C. P. Sills..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto,

1. K. H. Smith..........................Box 429, Kamloops, B.C.
Assistant Hydrographer, Departmt. of the Interior.

3′. M. L. Smith..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. R. G. Sneath..........................Toronto, Ont.
Post-graduate Course in Enigneering, University of Toronto.

3′. L. V. Soules..........................50 Tiverton Ave., Toronto.

3′. G. E. Squire..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. W. S. Steele..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

5. A. E. Stewart..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3. R. O. Stewart..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. R. A. Story..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. C. F. Szammers..........................1367 King St. W. Toronto, Ont.

3. R. Taylor..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1. J. B. Temple..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

3′. G. C. Thomas..........................Barrie, Ont.
Assistant Manager, Simcoe Fruits, Limited.

1. R. D. Torrance..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.

1911—*Continued*

1. W. G. Tough.........................Toronto, Ont
Post-graduate Course in Engineering, University of Toronto.
1. N. Vickers...........................Renwick, Ont.
2. J. H. C. Waite.......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. W. D. Walcott........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. G. L. Wallace........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. A. Wardell...........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. F. E. Watson.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. P. G. Welford........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. A. G. Wheler.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3. G. H. Wilkes.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
5. E. R. Williams.......................Toronto. Ont.
Post-graduate Course in Engineering, University of Toronto.
3. H. A. Wilson.........................Glenora, Ont.
3'. C. S. Wood...........................2066 3rd Ave. W., Vancouver B.C
With Electrical Construction Co.
1. W. G. Worden.........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. W. J. T. Wright......................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
1. F. H. Wrong..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
2. W. H. Wylie..........................Toronto, Ont.
Post-graduate Course in Engineering, University of Toronto.
3'. H. K. Wyman..........................Essex, Ont.
3'. L. P. Yorke..........................Thorold. Ont.
Electrician, Coniagas Reduction Co.
1. S. Young.............................Toronto Ont.
Post-graduate Course in Engineering, University of Toronto.
3. A. Young.............................Toronto, Ont.
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